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VOL. VI. NEW YORK, MAY, 1901. No. 3.

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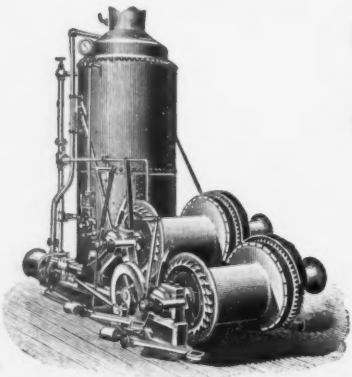

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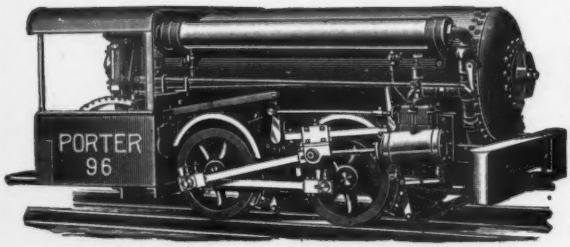

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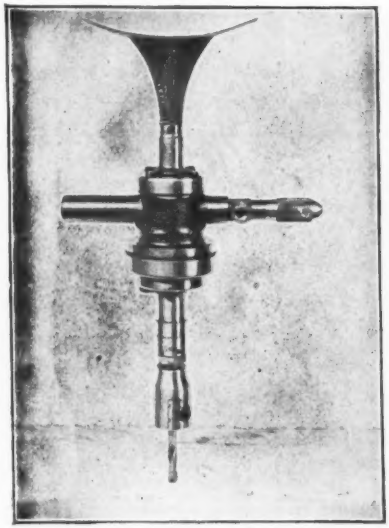

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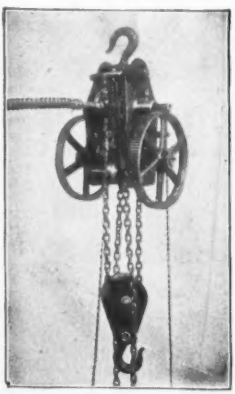

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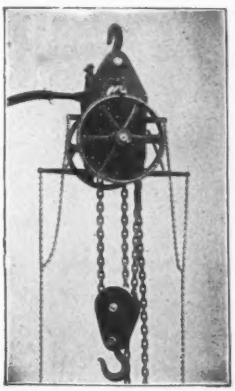

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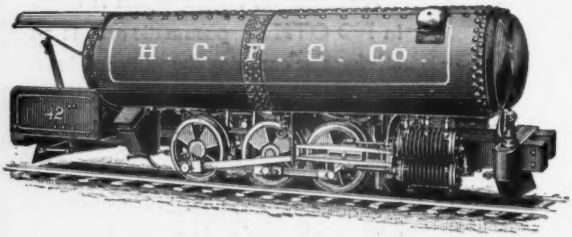

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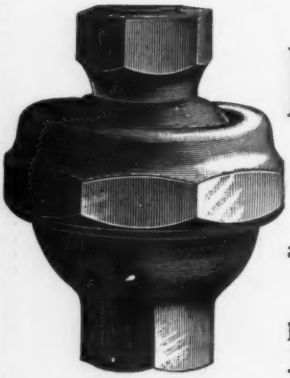

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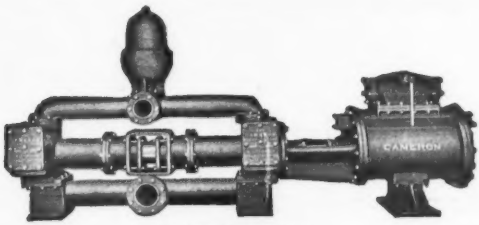

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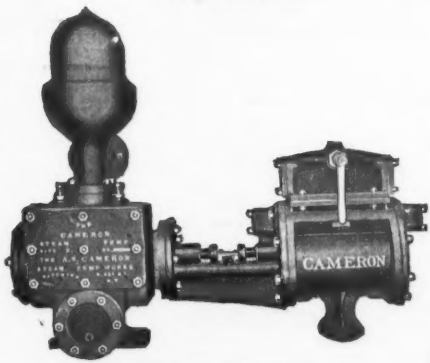

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VOL. VI. MAY, 1901. NO. 3.

Through the New York papers attention has been drawn to an accident which occurred to one of the compressed air cars of the Metropolitan Railway System, operating on the 28th and 29th streets cross-town line in New York City.

From the accounts one gains the impression that a very serious accident happened, endangering the lives of a great many and creating much excitement in the neighborhood.

We have very thoroughly investigated the accident on our own responsibility and in justice to the company we take pleasure in stating the absolute facts of the case so that our readers may judge for themselves.

We do not wish this to be understood as any argument for or against compressed air traction, but rather as an attempt to insure that justice is done to all concerned.

It appears that on March 27th at about 5.40 A. M., car No. 592 was run out of the station by the "hostler," as is customary, preparatory to starting on its regular run cross-town, when without warning there was a loud explosion, which damaged the car and broke a window of a saloon opposite where the car was at the time. The report created considerable excitement, but aside from the broken window in the saloon and the injury to the car there was no further damage done. The car was at once returned to the station for repairs on its own wheels and was put in operation within a short time at the total repair expense of $25.86. This cost included absolutely all work done in repairing the damage and in making certain adjustment of parts which are made at frequent intervals in any case. This amount, $25.86, was made up from the time slips of the men engaged in the work and is exact. It effectually refutes the statement that the car was blown to pieces, etc.

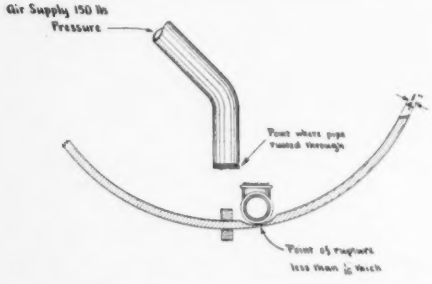
In order to understand this accident and to appreciate its peculiar character we present sectional views of the reheater tank which was the part of the apparatus that exploded.

This system as a whole was quite fully described in one of our recent issues, but for the sake of completeness, we review briefly the salient features of the apparatus.

In outward appearance the car resembles the usual street railway car. Under the body, however, and mounted on the trucks are 14 Mannesmann steel bottles, capable of standing a pressure of over 5000 pounds per square inch and tested in every case to 3500 pounds. The total storage capacity of these bottles is 55 cu. ft. and the storage pressure is 2500 pounds per sq. in. Air from these

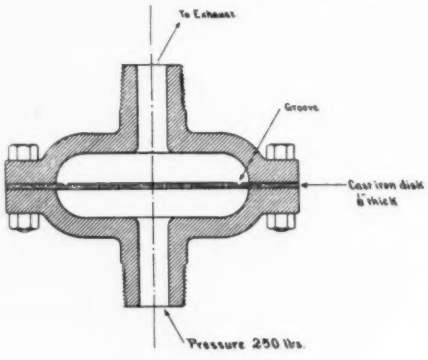
bottles passes through a special reducing valve in which the air pressure is dropped from 2500 pounds to 150 pounds per sq. in. and then passes into the "reheater tank" from which it is drawn off to supply the cylinders of the engine used to propel the car.

As the ultimate efficiency in the use of compressed air is very largely increased by heating it just previous to its actual use, these reheaters are essential. They are extremely simple in construction and satisfactory in operation, the air under a pressure of 150 pounds passes over and down through a tube inside of the



tank to the branch pipe seen at the bottom. This branch pipe has a series of small holes drilled in its upper side and extends nearly the entire length of the tank. As the air issues from these holes it bubbles through the hot water with which the tank is partially filled and collects in the tank over the water surface at a temperature of perhaps 250 or 325 degrees. From here it is drawn to run the engines as already explained. The perforated pipe or distributed pipe inside of the tank is held in place by three studs which screw through the tank and into the pipe as seen in the figure.

Owing to the constant jarring due to the vibration of the car, this pipe broke away from its supports and the central pipe and dropped to the bottom of the tank. The constant stopping, starting and jarring of the car resulting from a travel of about 90 miles per day for about two months caused this tube to shift back and forth and wear on the bottom of the tank. Singular as it may seem this wear was sufficient to reduce the thickness of the tank on the bottom from its original thickness of ¼ of an inch to less than 1-16 of an inch for a distance of 5 feet. As shown in the

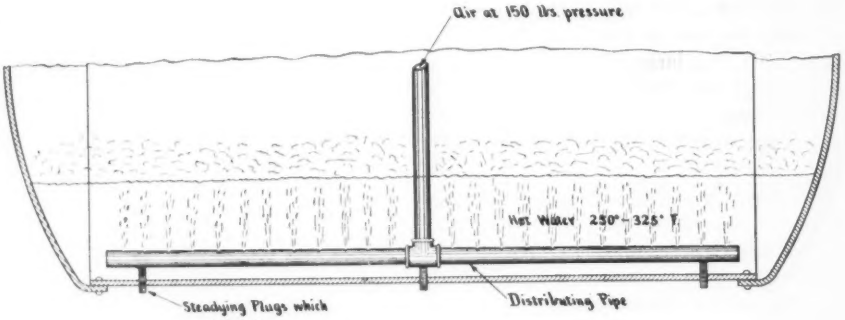


Hardie Safety Disk.

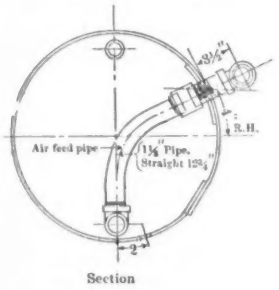
figure, this thickness was insufficient to stand the working pressure of 150 pounds per sq. in. and simply gave way; the tank bursting on the bottom along its entire length allowing the water to be thrown into the street with considerable force and noise, but without any material damage to the car or surrounding objects.

The pipe and the tank have been carefully examined by us and the accompanying sketch affords an idea of how this wearing occurred and its exact location. This defect of construction was being remedied and the cars were being taken off one by one to have the pipe fixed so that it could not possibly get loose inside of the tank, but no one imagined that a piece of loose pipe shifting back and forth could wear away the metal of the tank as rapidly as did actually occur.

The statement has been made that the real cause of the explosion was the failure of the reducing valve to work perfectly and the consequent discharge of air under 2000 pounds pressure into this reheating tank which is built to withstand only 300 pounds, the working pressure being only 150 pounds. Such an accident is an impossibility for the reason that the tank has two safety valves attached directly to it. One set at 175 pounds or 25 pounds above the working pressure and one at 200 pounds or 50 pounds above the working pressure. In addition there is a special safety disc shown in accompanying sketch which is so constructed that the pressure cannot possibly go beyond about 250 pounds without bursting. The disc performs the same function as the "fuse" in an electric car. This is nothing more or less than a cast iron disc about ⅛ inch thick and 3 inches in diameter which is placed over the end of the pipe connected with the receiver in such a manner that if the pressure exceeds the set figure (250 pounds) the cast iron plate bursts, exposing the entire 3-inch opening, which is amply large to allow all of the air in storage to escape harmlessly into the air.



Reheater Tank.



Section

The hot water contained in the reheater tank is heated by allowing steam to pass into it at the charging station. As this steam is taken direct from the boilers of the power plant the working pressure of which never exceeds 150 pounds it will be seen that there is no possibility of the water pressure of itself exceeding the amount due to a temperature of from 300° to 325° F., or about 85 pounds per sq. in.

We had the pleasure of riding on the car which was reported to have been blown to pieces, and aside from two new window panes we were unable to find any evidence of the accident.

Suspension of Air Car Service on the 28th and 29th Street Lines, New York.

The large installation, comprising about twenty cars operated by compressed air on the 28th and 29th street crosstown service in New York, has attracted a great deal of attention because it is the first experiment on a large scale looking to solve the street car problem by the use of compressed air. Many difficulties have been encountered and much valuable experience gained. Since our last issue, this service has been discontinued, and the following letter from Mr. Henry D. Cooke, President of the Compressed Air Co., explains the situation, and will tend to clear up the many uncertainties which have arisen through unauthorized newspaper statements:

COMPRESSED AIR CO.,
621 BROADWAY, N. Y.

May 2d, 1901.

W. L. Saunders, Esq., 26 Cortlandt St., New York City.

Dear Mr. Saunders:

I take pleasure in sending you herein copy of letter written me a few days ago by Col. Ashley W. Cole, Chairman of the State Board of Railroad Commissioners of the State of New York, in regard to the breaking of the reheating cylinder on Car No. 592, on 24th street, on March 29th. The report from which he quotes is a complete vindication of air in this matter, the newspaper accounts of which were so grossly exaggerated. This car was in service the next day with a new reheating cylinder, with the pipe referred to specially held on brackets in the centre of the cylinder in a manner to absolutely prevent the possibility of a recurrence of the accident.

This car was one of twenty which were operated for six months and two weeks on 28th and 29th streets, this city, during which time they carried 3,250,829 passengers, and on the last day of service these cars carried an average of more than 1,100 passengers per car, one carrying as high as 1,673 passengers, another 1,566 passengers, another 1,486 passengers, etc.

These cars have been withdrawn from service on 28th and 29th streets, and we are changing the heaters on them and strengthening the moving parts of the machine. We have had the same experience the electrical people had when they first started, and, in endeavoring to secure lightness in construction, we have not made the running parts of the motor heavy enough to withstand the severe strain of such service as these motors have had on 28th and 29th streets. Not only were the loads exceedingly heavy, but there are twenty-five curves on the line, and the cars have been very roughly handled by the motormen, due to the fact that the lever and other platform devices on the cars left too much to the judgment of the motormen. These are being very much simplified in the new motors, and we are building heavier axles, which means bigger journals, strengthening wheel centres, and adding weight and strength to all the moving parts of the machine. It is very probable that the present motors will be strengthened up and put on some road in this city where the conditions of service are less exacting. Meantime, we have every confidence that the new motors we are turning out will meet the requirements of crosstown service.

During all the time that air cars have been operated there have been no serious accidents and the high pressure end of the system, both at the compressing plant and on the cars has been proved beyond peradventure. We feel there is a large place for air in the railroad situation, and the fact that these cars can be run over an or-

dinary track without any special construction, which is expensive in first cost and in maintenance, will recommend them for general use in cities. They have a special use during rush hours to carry the peak of the load with air which can be compressed during the light hours of the day, which would enable existing plants to largely increase their carrying capacity during the rush hours.

In this connection, I beg to call your attention to the fact that the air cars installed about two years ago on the North Clark street line of the Union Traction Company's system are still running and giving good satisfaction, and that the entire street railroad system of Rome, N. Y., is entirely operated by air cars.

Trusting the above will be of interest to you, I am,

Yours very truly,
HENRY D. COOKE.

STATE OF NEW YORK

BOARD OF RAILROAD COMMISSIONERS.

Albany, N. Y., April 29, 1901.

Henry D. Cooke, Esq., President Compressed Air Company, 621 Broadway, New York City.

Dear Sir:

Referring to your letter of inquiry concerning the accident on 24th street, on March 29th, would say that this was caused by the bursting of the reheater cylinder, as will be seen from the following extracts from the report of the Steam and Electrical Experts of the Board of Railroad Commissioners:

"The accident which occurred on Car No. 592 was caused by the bursting of the reheater cylinder. * * *

"This was undoubtedly due to the lower perforated pipe in the cylinder becoming broken from its fastenings and lying loose on the bottom of the cylinder and oscillating on the plate of the cylinder. The oscillation was caused by the motion of the car and the action of the air entering the cylinder. A groove had been worn in the steel plate of the cylinder as perfect and true as though done by a tool, reducing the thickness of the middle of the cylinder to less than 1-16 inch. * * *

"It will be seen from the above description of the operation of compressed air as a motor power for street surface cars, that this was not an explosion caused by compressed air under high pressure contained in the reservoirs on the car, but was the fracture of a reservoir containing hot water and compressed air at a pressure of not more than one hundred and fifty pounds to the square inch." Yours truly,

(Signed) ASHLEY W. COLE, *Chairman.*

The sudden and unexpected death of Richard P. Rothwell on April 17th has removed from the field of technical journalism one of the best known editors who, at the same time, was an author of prominence and a mining engineer well known both here and abroad.

Mr. Rothwell was born on May 1, 1836, in a little Canadian town "Ingersoll," and after a preparatory course at Trinity College, Toronto, he entered the Rensselaer Polytechnic Institute, Troy, N. Y., whence he was graduated in 1858 with the degree of Civil Engineer. To continue his studies and obtain a broader knowledge of engineering, he went to Paris and entered the Ecole Centrale des Mines, and graduated as an Engineer of Mines in 1862.

In 1862 he returned to the United States and located in Wilkesbarre, Pa., where he continued to practice in the capacity of Consulting Engineer for several large collieries.

In the spring of 1871 Mr. Rothwell suggested the formation of a Society of Mining Engineers, and on the 16th of May the organization of the American Institute of Mining Engineers was perfected. With this association he has been prominently connected ever since in various capacities from Manager to its President.

Later in 1874, he became the editor of the *Engineering and Mining Journal,* and afterwards its owner.

In addition to his many duties connected with the editorial and business management of the *Journal,* Mr. Rothwell made a most elaborate study of mining statistics and became, in 1893, the editor of the annual publication of what is perhaps the most comprehensive statistical mining review of the whole world known as *"The Mineral Industry."*

In addition to his many duties and the arduous work connected with the management of the *Engineering and Mining Journal* and the preparation of his books, Mr. Rothwell was a member of a large number of clubs and societies, both here and abroad.

Uses of Compressed Air.

By the steady advance of compressed air into every branch of industry, new devices for employing this pliant force are of daily note. The railroads have been prompt to take advantage of the economies secured by the use of air tools and were among the first to employ compressed air for general shop requirements. Beginning with a discarded air-brake pump as a source of air power, their necessities grew so rapidly that in a very short time compressors of economical design and large capacity were put in service.

APPLICATIONS OF COMPRESSED AIR IN RAILWAY SHOP PRACTICE.

"The consideration of compressed air is certainly timely, for in no branch of the engineering profession is there anything receiving now more attention or arousing greater interest than compressed air and its applications; nor, indeed, is there anything which by reason of its possibilities, merits more attention.

"Wherever steam has gone to create the necessity and opportunity for it, there compressed air has followed, going often

FIG 1.

The uses the railroads make of compressed air are so varied that, in order to show what can be accomplished in the general machine shop, the boiler, bridge and woodworking shop, in painting, renovating and general repair work, we cannot do better than quote verbatim from the following valuable addition to compressed air literature embodied in a paper read before the St. Louis Railway Club by Mr. Edward C. Schmidt, instructor in Railway Mechanical Engineering, University of Illinois. Subject:

where steam could not go, rivalled only in its adaptability and convenience by electricity.

"In all branches of industry and manufacture it has its hundreds of applications, and this is no mere figure of speech, for there lies before me a list of nearly four hundred different uses of compressed air, and that this list is complete and that it is not daily becoming less so, it is vain to imagine.

"Its uses in civil engineering have long been familiar to us, and it is certain in

the development of tunnel construction and caisson work it has been the most important factor.

"In mining operations, in the blast furnace and the converter, in bridge building, in ship building, on war vessels, on railroads, in shops of all kinds, and in car and carriage propulsion we have the most familiar evidence of compressed air, and, without citing obscure or trivial uses, this short list could be very much extended.

"Compressed air in railway uses is the subject to which we will confine our attention, and more particularly to the uses of compressed air in railway shop practice.

"The first and most important application of compressed air in railway work—I refer, of course, to the air-brake—is now a matter of only a few years of age, and yet nothing else, perhaps, in the history of railroads has contributed so much to their development as this. Indeed, very few other inventions in any field of industry have the claims to the consideration that must be awarded to the air-brake. It is sufficient for a realization of its importance to ask you, who are all so familiar with it, to imagine the state of a railroad to-day if deprived of its air-brakes.

"It may be the familiarity with the use of the air in the brake, and the respect aroused for it by its years of faithful service, or, what is more likely, it may be the unusual alertness of railroad men in the discovery of time-saving devices, is responsible for the hearty reception that compressed air tools receive among them. Be that as it may, it is certain that to-day air is more widely used and that its advantages are more thoroughly appreciated in railroad shops than in other places.

FIG. 2.

"In the maintenance of way department, we find many applications of air all-important, but by which we must hasten. Compressed air signal systems and switching systems are so usual as to need no comment, performing their work with a certainty that is essential above all things and performing it often in situations where no rival system could succeed.

"In bridge building, pneumatic tools

are as useful and as economical as those which we shall notice presently in operation in the shops.

"In track-surfacing, supplanting the laborious and oftentimes unsatisfactory process of tamping, compressed air has been used with success, although this use is comparatively infrequent. On the train in service we find in addition to the all-important air-brake, the pneumatic signal, the pneumatic bell-ringer, and the pneumatic track-sander, all devices which supply the qualities of reliability and convenience when they are most needed.

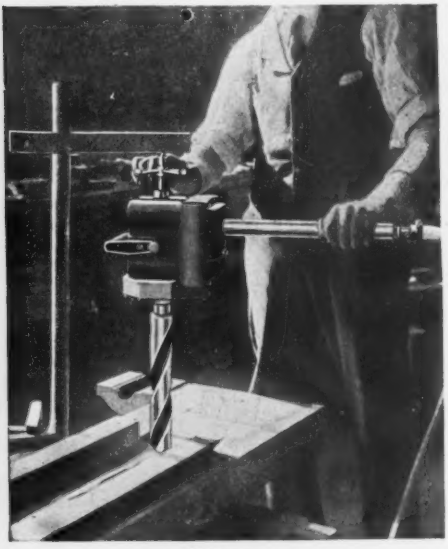


FIG. 3.

"Useful as compressed air is in all these branches of railway work, it is not until we consider it in the shop and in the yard that we see it at its best in its field of greatest usefulness. For the multitudinous requirements of a railroad shop compressed air has only one rival as a transmitter of power, and that is electricity, which is, however, no longer a very dangerous rival. Hydraulic transmission has so many and such apparent limitations as to be entirely removed from the competition.

"In case of transmission and of application, in adaptability as well as in cost of installation and maintenance, air and electricity are almost on an equal footing, and it is only when we consider the tools by which this power is applied that we find the advantage of the former over the latter. It is in the greater simplicity of the motors required for local application that air may base its claims to distinction.

"In addition to the important difference in cost, due to the greater simplicity of construction, the air-driven tool possesses the advantage, so requisite for its proper use, of being readily understood by the operator—a claim which cannot be made for electricity for some time to come, for the confusion and dread in the ordinary mechanic's mind of all things electrical, are not so soon to be dispelled.

"We shall now make a tour of the various departments of the railway shops, stopping only long enough to notice the different tools in operation, or, perhaps, in some cases to get the opinion of the work done by them from those in charge.

"Beginning in the foundry we first find air in use in the cupolas and exhausters, but we pass these by without further notice, although these applications are certainly important enough.

"The most prominent tool in foundry work is the pneumatic hoist. For handling the copes and cores it has the necessary requirements of ease and precision in manipulation, and, indeed, for all, except the heaviest work in foundries it may find its uses. In one shop, an air hoist, with quick exhaust, was seen tamping the earth around a newly-built furnace, and the thought is suggested that it might possibly be put to similar use in the larger moulding work in the foundry, where it is already installed for other purposes.

"The pneumatic hammer (Fig. 1) is particularly well adapted for foundry use, for it is in such light work as is usually required in chipping and cleaning castings that this tool attains its best speed. The amount of work done by one man with the hammer varies from three to four times that done when chipping by hand in general foundry practice, the greater being realized in lighter work, as intimated above.

"In machine shop work the pneumatic drill has undoubtedly more applications than other tools, and the illustration (Fig. 2) exhibits most strikingly its application in a situation where its use must commend itself at once to all who know what ratchet drilling means in this case. In

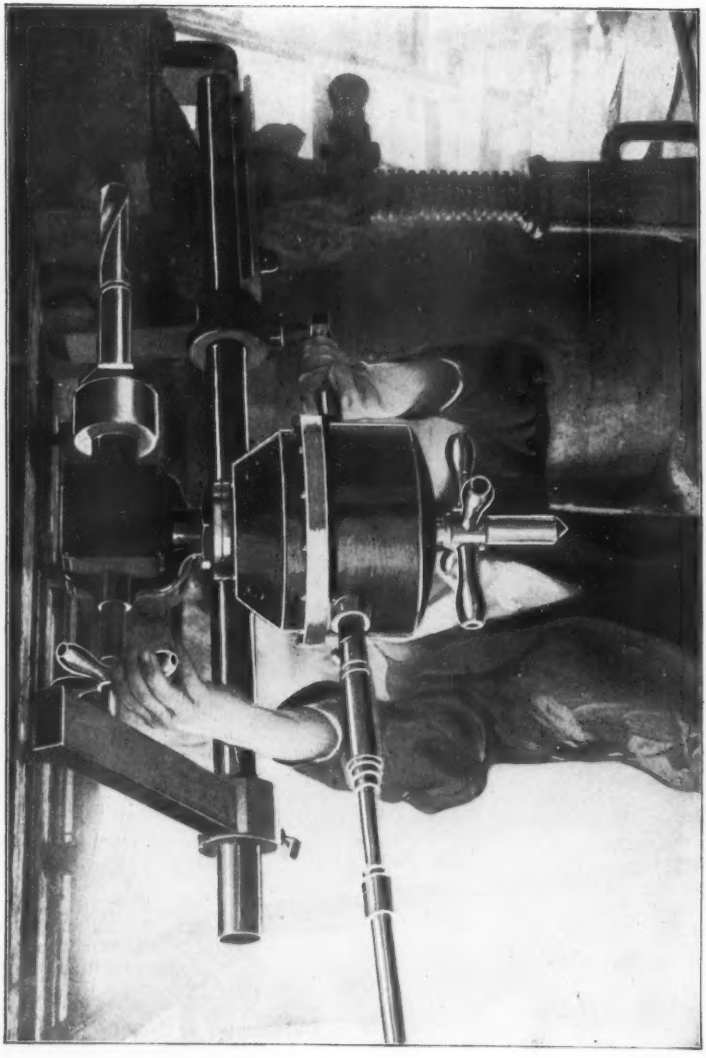


FIG. 4.

many other instances where the drilling of the locomotive saddle by the ratchet is out of question, the saving in time and labor effected by the air-drill in avoiding the transportation to the drill press of a saddle weighing several tons, is greater perhaps than that following the use of this tool in most cases.

"In a particular piece of work on saddles, typical of many situations in which the pneumatic drill is used, a machinist and helper accomplished in three hours

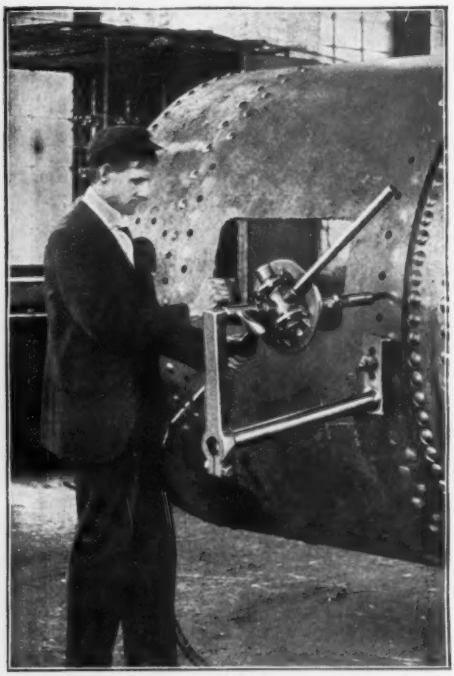


FIG. 5.

what would have required by means of the ratchet drill sixteen hours, and this saving of seventy per cent. is by no means extraordinary, very much less in fact than that effected in the case just preceding.

"It is noteworthy that the time required for drilling the work shown in Fig. 3 was about the same as it would have taken to drill it at the drill press, and the maximum power obtainable from this form of drill —about two to two and a half horse power—is also about what would be required by a drill press upon which such work would be done. The next illustration (Fig. 4) shows how the drill by the use of a pair of bevel wheels can be made to reach the most inaccessible places. A fourth style of drill is shown in Fig. 5. In one of our Chicago boiler shops the time required for work done by the pneumatic breast drill was to the time consumed by the same work when done by hand-driven tools, in the ratio of one to ten or one to twelve.

"The ease and comfort obtained in the use of compressed air tools is a point in their favor not always considered as much as it ought to be; for anything which tends to make lighter many of the operations in railroad work which are necessarily laborious and performed oftentimes under the most trying circumstances, is worthy of consideration on this account if on no other.

"The various other uses to which the motors of these drills may be put present themselves at once, and by one of these applications (Fig. 6)—the grinding and facing of steam pipes—there is now accomplished in fifteen minutes what formerly by tedious hand work, needed an hour or more.

"In all places where a small amount of power is desired, the air motor of the drill is applicable, and it is in common use for driving boring bars and small lathes. Its steadiness of operation under such conditions is remarkable, and it is this characteristic which has caused it to be used in the mechanical laboratory of the University of Illinois in experimental work, where high and very uniform rotative speed was a necessity.

"The photographs from which these illustrations were made were taken for the most part in three of the largest railroad shops in this part of the country, and in addition from several machine shops and boiler shops in the vicinity of Chicago.

"The figures relating to saving in time and labor were, without exception, obtained from the master mechanics or general foremen, and the figures thus given were in almost every case verified by consultation with the shop foremen and operators themselves. Care has been taken that such figures represent ordinary conditions, and records made particularly for showing a saving or under unusually favorable circumstances, have been excluded or modified, so that the figures given

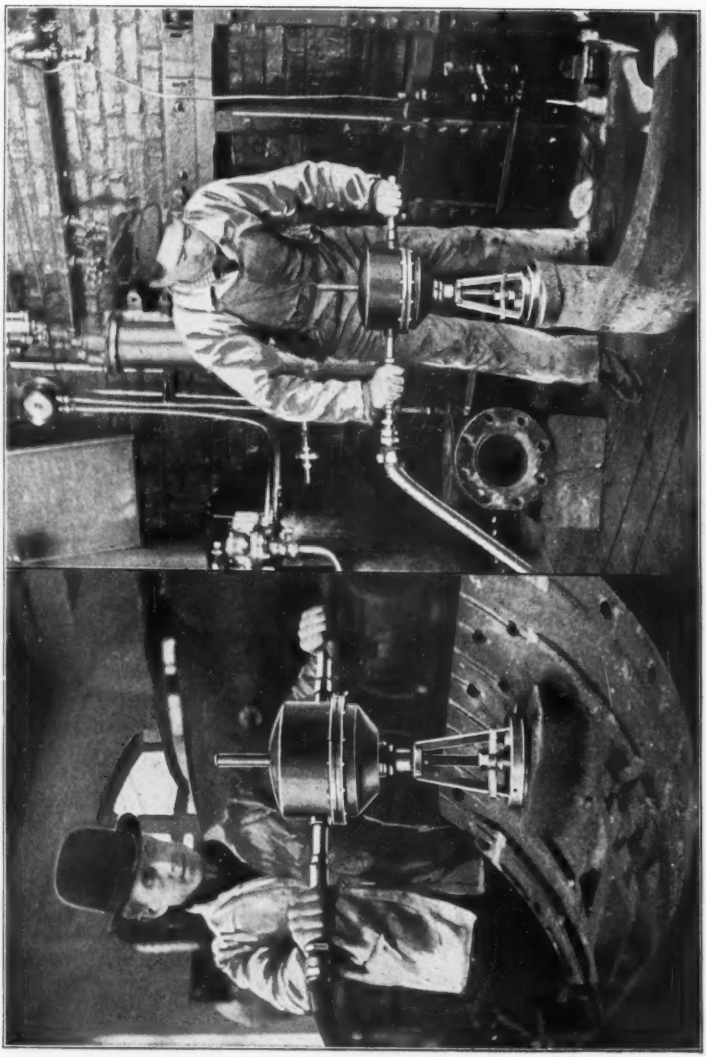


FIG. 6.

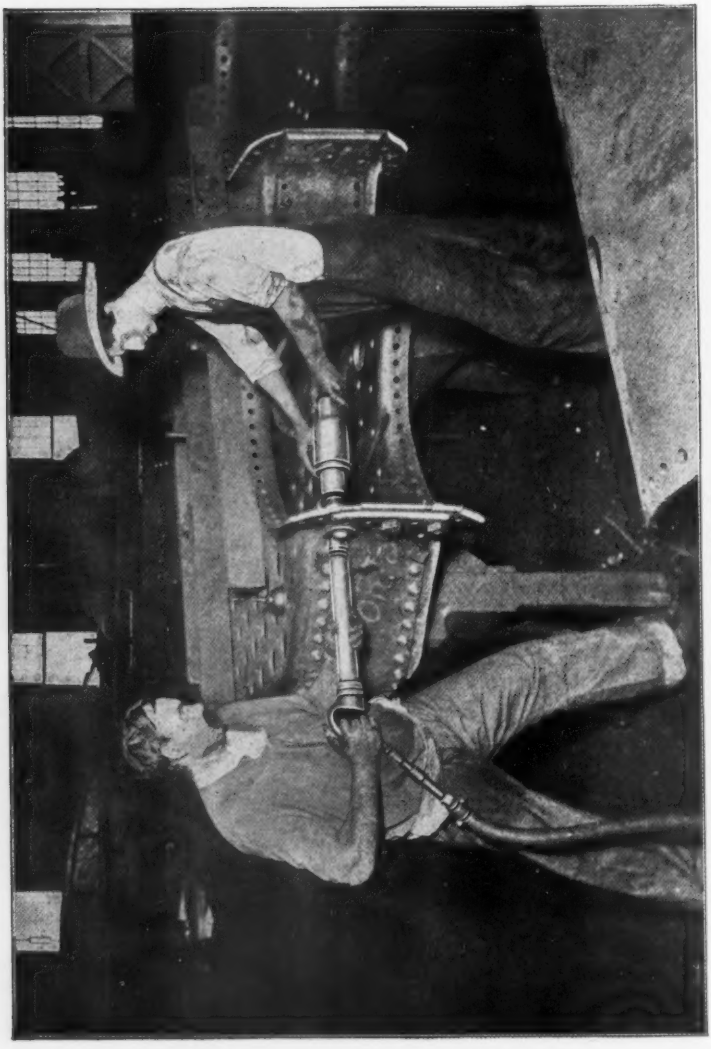


FIG. 7

may with reason be relied upon for the conditions mentioned and under which they are obtained.

"In one of the railroad shops, and that the one from which more than its share of information has been drawn, the transition from hand work to the use of air tools has been undergone within the last eighteen months, and many of the figures are derived from daily records, and all the information is fresh in the minds of those concerned. In all other cases where the figures given were not based on written records, the results, as intimated, have been carefully scrutinized.

"Passing now to the boiler shop, the first thing we see is the pneumatic hammer, which is here in its especial work. This,

FIG 8.

the pioneer of pneumatic tools, has entirely changed the character of much of boiler-shop work, and there are doubtless more pneumatic hammers in use than any other air tools. For chipping, caulking, beading and riveting it has almost entirely displaced the hand tools.

"For riveting, the use of the pneumatic holder on, shown in this illustration (Fig. 7) adds much to the tightness of the work. In one of the above mentioned shops, in riveting by the air hammer, the mud ring on a consolidation locomotive, the saving realized over riveting by hand was 67 per cent., and this class of work is typical of much of that done by the hammer.

"One of the most interesting operations performed by the pneumatic hammer is the chipping of wrought iron and steel (Fig. 8). To one who has tried to take off with a hammer and chisel such a cut as that being removed from the flue sheet before you, it is astonishing to see the ease and speed with which such work may be done by air, although it is not so remarkable after all, if we consider that from 4,000 to 6,000 strokes are claimed for these hammers. In one instance, in work of this character done on a "ten-wheeler," the work formerly requiring the labor of a boiler-maker and helper for two days is now done in one-quarter of that time.

"The hammer used for flue beading effects about the same saving as it does in other classes of work. To bead 250 flues by hand costs $2.35, while the same amount of work, with the aid of air, amounted to 60 cents.

"The portable riveting machine with fixed yokes, such as those now shown (Fig. 9) can, of course, do better work than the hand hammer, and for a great variety of work will produce as good results as the stationary pneumatic riveter, than which it is much more convenient. 'With these riveters,' to quote the foreman of the boiler shops referred to above, 'we can do with three men (two boilermakers and one helper) twice the amount of work formerly done with three boilermakers and one helper riveting by hand.' These machines will operate successfully on plates up to about seven-eighths inch in thickness, without their having been previously drawn together, and for work of this class will compete in their results with hydraulic riveting. Indeed, the foreman of this same shop informed me with considerable satisfaction that work done by one of these riveters had been inspected and passed as hydraulic riveted, a few days previous, by an inspector of one of our best-known boiler companies, who was with difficulty convinced of his mistake.

"The air-operated nippers shown here (Fig. 10) cut off in one case all the stays in the firebox of a Brooks "ten-wheeler" in three hours, when handled by two boys, a job which formerly occupied a boiler-maker and helper nearly two days. This is a saving in cost of about 90 per

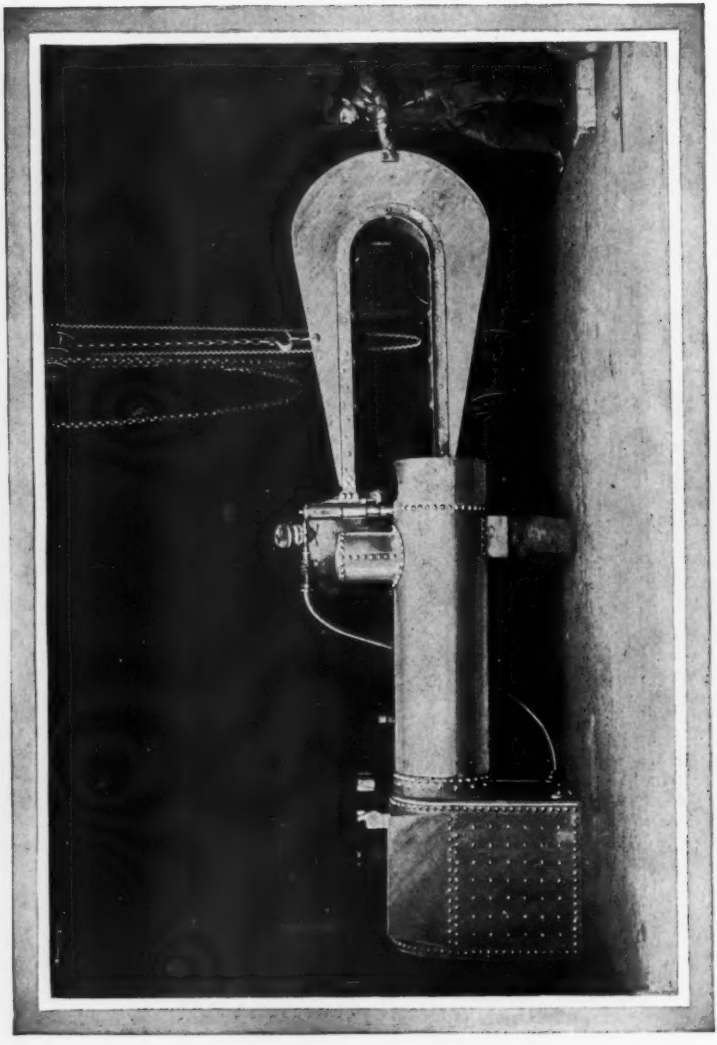


FIG. 9.

cent., and the same work with this tool in another erecting shop resulting in a saving of 86 per cent. The figures include in both cases, the time required to get and set the tool. Furthermore, the nippers cutting off from both sides at once, do not injure the sheet or loosen the thread as may be done by chipping them off.

"We shall notice next a few applications of the drill in boiler shop practice where its uses are as manifold as we found them to be in the machine shop. In drilling and tapping and reaming, it has almost limitless uses, and it gets into nooks and corners where otherwise ratchet work would need to be resorted to.

"The next illustration (on cover) shows the drill motor with the flue cutting attachment. It is air-driven and the feed, too, is operated by air. From information derived from several sources we find that it cuts out flues at the rate of from two to four per minute, depending on their location. Besides this saving in time, there is less waste and the tubes are left in better condition than when removed in the old way.

"Another use to which the motor is put is shown in Fig. 12, where we see the pneumatic flue roller, by the use of which one man can do the work of two, under some conditions, of three men, rolling in the old way. It seems very likely that with proper attachments, the motor could be successfully used for cleaning boiler flues and tubes. Besides these uses of the drill may be mentioned its applications in tapping, reaming, screwing in stays and bolts and putting on nuts.

FIG 10.

"The next illustration (Fig. 13) shows an apparatus not unlike the paint-burner, which will be noticed later, and which is an oil-burner for heating and expanding driving-wheel tires. Compressed air is led through crude oil contained in the tank, carrying the oil out through the burner, the arrangement being, in fact, a large atomizer. Its advantages over the

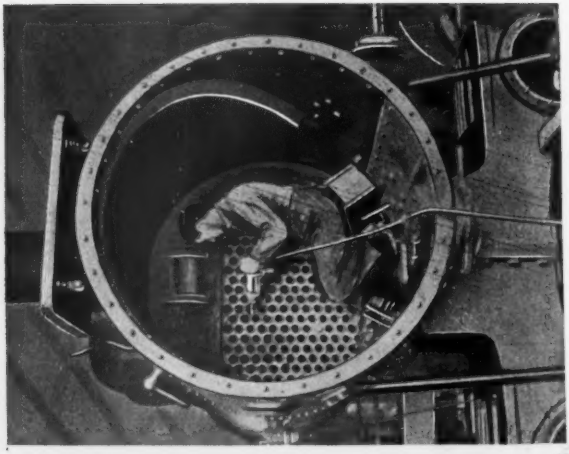


FIG. 12.

FIG. 13.

usual wood fire are apparent, for it can be applied just where heat is needed. This facility of application has its usual effect in the saving of time.

"Passing now to the car shops, and proceeding as rapidly as possible, we may note the drill again at work (Fig. 14)—this time on wood—a drill, of course, adapted to this purpose, running at a higher speed than the metal drill and weighing usually not more than 12 or 15 pounds. One of these tools has a record of boring through 5 inches of oak a 2½-inch hole in less than twenty seconds—a statement that is particularly

FIG 14.

significant to anyone who has ever tried to bore a 2½-inch hole in oak. This drill in the car shop and in rip-tack work produces a saving of time even greater than that effected by the drill in machine shop operations.

"In the paint shop we encounter immediately the paint sprayer (Fig. 15) which only a short time ago was looked upon as a novelty. Yet there are very few railroad paint shops to-day where the sprayer is not regarded as an absolute necessity. The saving to be effected by it varies, of course, by the character of the work. In general, the larger the area to be covered the greater the economy by the use of the sprayer, although the intricacy of the work modifies this. The saving in painting trucks is about 85 per cent., while in the case of box car painting the records kept for several days show a decrease in cost of 90 per cent.

"In the railroad yard, as in the other departments, the air hoist (Fig. 16) is the first thing to force itself on our attention, altered in form it is true to meet its new requirements, but still the same tool that we met with in the foundry and the machine shop, and if possible, even more useful here than there—more useful here in that it may be in more constant service. The economical handling of such material as is being loaded here is a problem not easily solved by any other means, and this solution is made the more easy by the fact that compressed air is of a necessity available in a railroad yard.

"The car-journal turner seen here (Fig. 17) illustrates very forcibly one of the fundamental reasons for the general success of pneumatic tools, namely, the ability of local application and the avoidance of outlay of time and labor in transporting the work to the tool.

"We have here a machine operation transferred out of doors and a car-journal being turned almost in its original position. This tool takes two cuts and a finishing cut on a car axle in about an hour. The ordinary drill is its motor and is detachable, consequently available for other work.

"On our way to the round house, which is now the only remaining place, we may notice their use of air (Fig. 18) which is typical of so many of its applications in the upholstery department. As a cleaner of carpets, cushions and hangings the air-jet is unrivalled, and it does in this class of work about twice as much as can be done by old methods, and that, too, without injury to the work, and with a thoroughness that is not approached by the usual beating process. In the round house we find air used for lifting sand and air and water, and it affords a neat and easy way of handling these materials.

"The pneumatic bell-ringer shows into what small details the compressed air movement has penetrated, and it gives us some intimation as to what we are

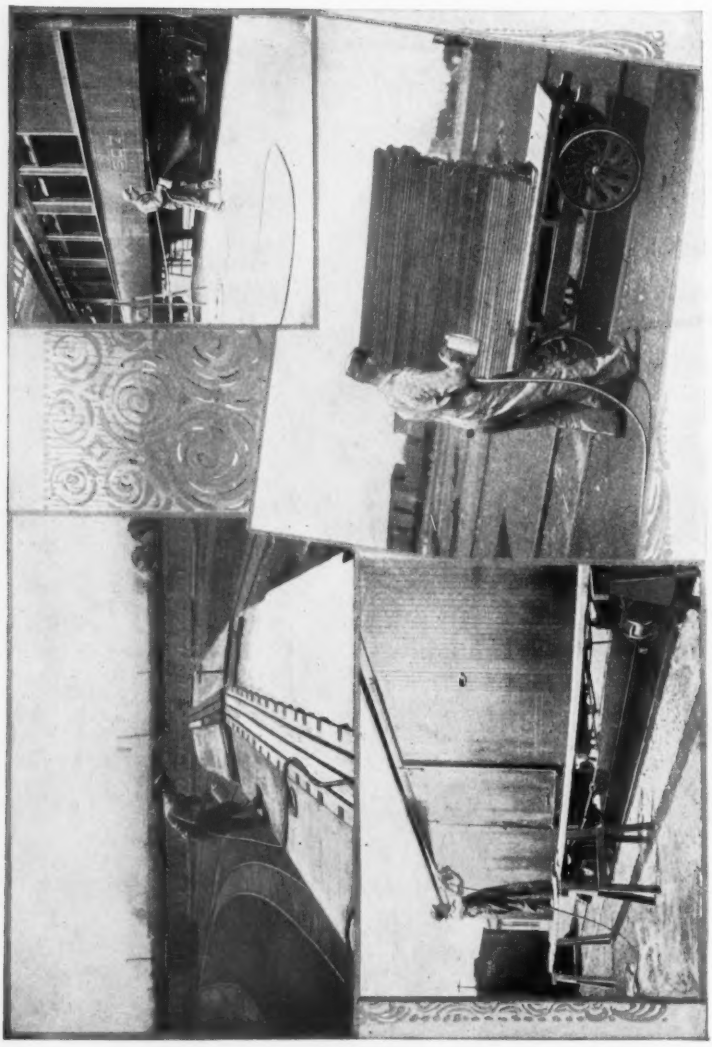


FIG. 15.

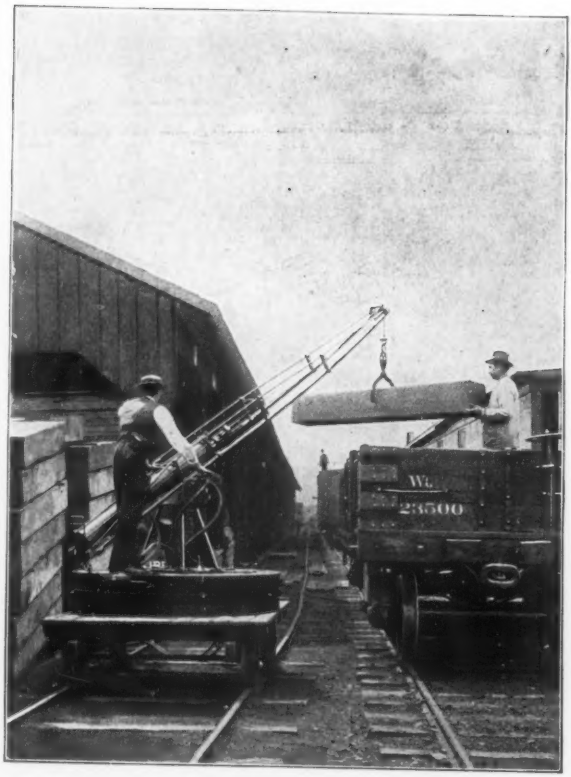


FIG. 16.

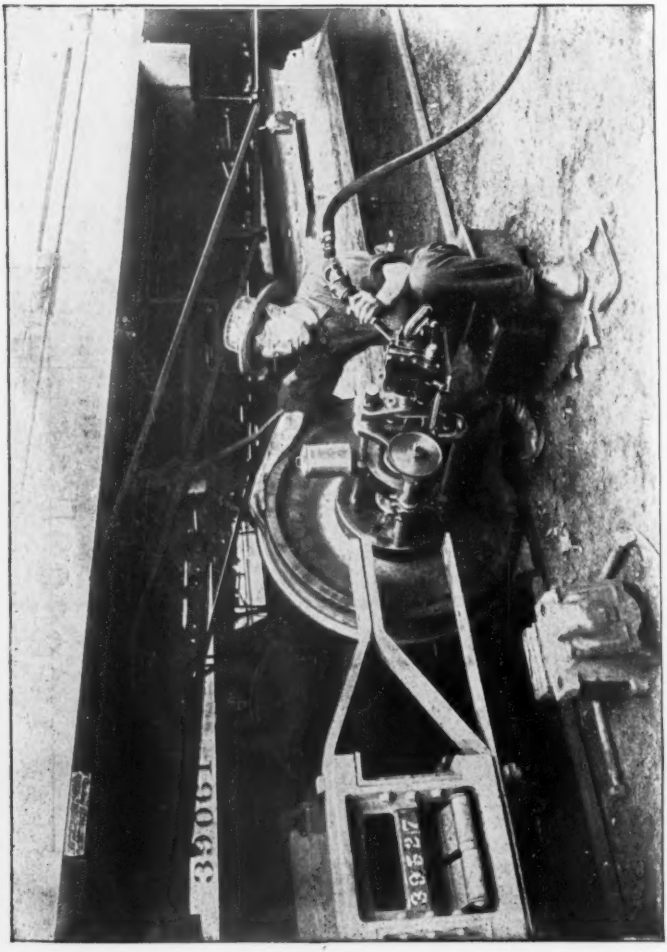


FIG. 17.

FIG. 18.

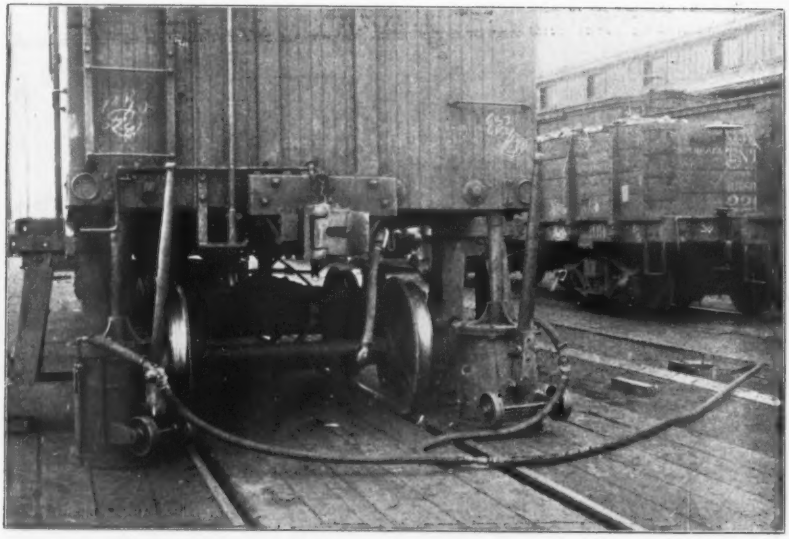


FIG. 19.

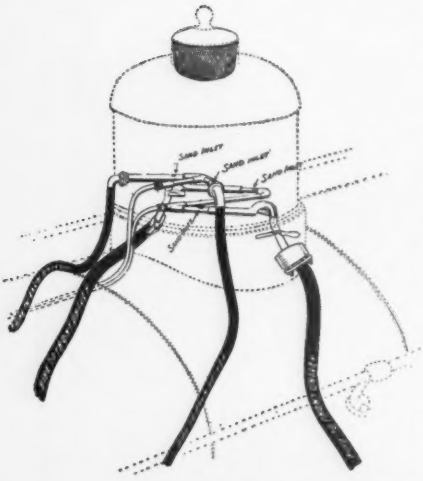


FIG. 20

coming to in this matter, for it is into such details that compressed air is bound to force its way. It may be that the overworked fireman would not concede that this application is so unimportant after all. We may mention, too, that other round house implement—the air jack (Fig. 19).

"The compressed air track-sander must be recurred to here, for it was too hastily dismissed when referred to before. Its reliability and certainty of action commends its use, and it must be counted one of the important applications of compressed air.

"The pneumatic fire-kindler here shown (Fig. 21) is an important piece of apparatus in the round house where this view was taken. It is only a compressed air oil burner of the simplest construction. It is used above the coal and without any kindling material.

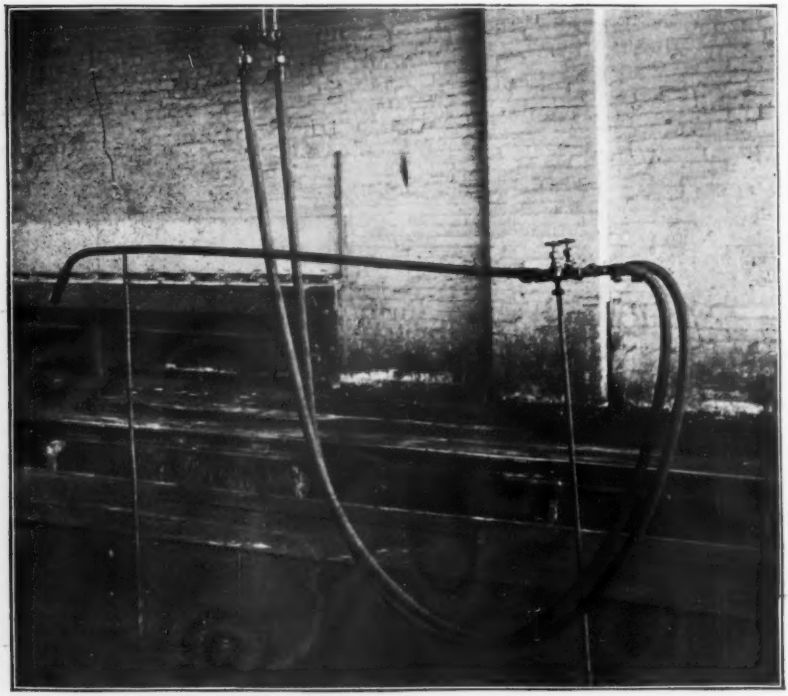


FIG. 21.

"Some of the results of tests conducted by the mechanical engineering department of the University of Illinois with this instrument may be of interest. The tests were made to determine the relative costs of kindling fire by wood and by crude petroleum, the latter being burned by means of the fire kindler shown here.

"The boiler pressure raised in each case was the same; the time required to reach this pressure was one hour and ten minutes kindling by oil and one hour and forty minutes kindling by wood. The total cost, which in each case includes the cost of labor, coal and the kindling material, amounts to 34 cents for oil and 61 cents for wood, on a basis of oil at 2½ cents per gallon and coal 75 cents per ton—a gain in favor of the oil of about 45 per cent.

"In the tables below are the averages of all the figures given in the foregoing. The figures, as previously stated, have been subjected to careful scrutiny before being accepted, and for the conditions to which they apply may be relied upon as accurate—in so far as accuracy is attainable in such matters. The conditions they represent are normal and such as present themselves in all shops. All extraordinary records or test cases have been excluded, and the results given may safely be applied in making deductions for conditions similar to this noted in the tables.

"Among the various men who have supplied the foregoing information, the most enthusiastic advocate of compressed air was the general foreman of a plant where 1800 cubic feet of air are used per minute, and where almost every one of the devices mentioned in this paper are in daily operation.

"It can no longer be said that the use of compressed air is in its infancy, nor can the old charges of unreliability and uncertainty in its action and of great wastefulness in its transmissions be substantiated.

"The use of compressed air in shops is no longer a subject of controversy. The field is already pretty well occupied, and the possibilities are clearly understood.

"In view of the active interests displayed in the subject in all quarters, it is inconceivable that its development should not continue to be rapid, and with this development will come the perfecting of pneumatic tools and the improvement in their ultimate efficiency, which in consideration of their present gross economy is not just now so essential."

Tool.	General Character of Work.	Saving Per cent. of cost.	Saving Per cent. of time.
Pneumatic Hammer	General Foundry Work—Chipping	67—75	67—75
" "	Riveting on Mud Ring and Fire-box	67	..
" "	Chipping Flue Sheet	84	75
" "	Reading Flues	75	75
" "	General Boiler Shop Work	60	..
" "	Cutting Out Broken Fire-box Stays	70	70
" "	Cutting Off Stay-bolt Heads	58	..
Riveter	Boiler Riveting	66	50
Drill	Drilling Saddles	70	70
"	In General Machine Shop Work	75	75
"	Drilling for Stays	50	50
"	In General Boiler-work Shop	75	75
"	Facing Steam Pipes	75	75
"	Tapping for Stays	65	..
"	Reaming Crown Sheet	70	..
Breast Drill	General Work	90	90
Staybolt Nippers	Cutting Off Stays	73—90	75—90
Driving-box Press	Pressing Brasses	68	..
Paint Sprayer	Painting Box Cars	67	67
Paint Sprayer	Painting Car Trucks	87	87
Paint Burner	Cleaning Off Passenger Cars	67	67
Sand Blast	Cleaning Tanks	90	83
Air Jet	Cleaning Cushions	50	50

Compressed Air.*

Gentlemen:—

The subject for this evening is a broad one, but we will try to compress it as much as possible to avoid tiring you.

For this purpose and in order to proceed systematically we will touch on the historical side only enough to impress upon you the fact that the use of compressed air dates back to that time when Egyptian "promoters" were trying to

*A lecture delivered before the Brooklyn Engineers' Club, April 4, 1901, by J. J. Swann.

organize pyramid companies and the early capitalists were cornering papyrus.

Fortunately for history this "papyrus corner," which I am guessing at, did not prevent Hero of Alexandria from writing a book on compressed air known as Hero's Pneumatics" and published some time between 284 and 221 B. C., which was the span of Hero's life.

The devices described in this remarkable work were not all original, though the well-known "Hero's fountain" was. Most of these devices were the inventions of the tricky priests of his time and formed their stock in trade to conjure money from the hands of the ignorant and superstitious people who believed in almost anything.

All this was only play, however, and nothing of any real value was known until about the year 1662, when the fundamental law governing the compression of all gases was discovered almost simultaneously by two physicists, Boyle and Mariotte. Since then one by one other physicists have suggested theories or discovered the laws which constitute the science of thermodynamics as we know it to-day.

Much has been written about the theory of compression and expansion of gases, but time forbids any repetition of these discussions, essential as they are, and we must confine ourselves to the practical side of the science.

For our purpose it is best to employ the classes into which the subject naturally falls, namely:

1—Production;
2—Transmission;
3—Use.

To begin with, what is air? It is a material, a composite substance and in its ordinary form contains oxygen, nitrogen, carbonic acid and a certain amount of water vapor, the proportions being about 23 parts by weight of oxygen, 77 parts by weight of nitrogen or by volume the proportions are about 21 to 79.

This substance forms a shell or layer about the earth variously stated from 20 to 40 miles thick, being densest at the sea level, where its weight produces a pressure of about 14.7 pounds per sq. in. and shading gradually off into the ponderable ether about which physicists are wont to talk.

At the sea level or at atmospheric pressure and a temperature of zero degrees C (32° F.) one pound of dry air occupies a space of 12.386 cu. ft. At 60° F. the volume has increased to 13.089 cu. ft. per pound. Conversely the weight of a cubic foot of air under the conditions just outlined is 0.0807 pounds and 0.0764 pounds.

This is simply the demonstration of Boyle's Law, previously mentioned, which states that:

The volume of a body of gas varies inversely with the pressure, density and elastic force and directly with the temperature.

If we reduce the volume by compressing the gas, the pressure increases, the temperature increases, the density increases and the elasticity increases.

Now this statement suggests at once two ways of discussing the compression of a gas. We may either compress it at a constant temperature, abstracting the heat as the temperature tends to increase, called isothermal compression, or we may prevent the dissipation of the heat allowing the temperature to increase, which is called adiabatic compression.

Theoretically these are the two methods of compression—but as is so often the case, practice falls somewhat short of theory and we are forced to content ourselves with a middle course.

The mathematical statement of Boyle's law for perfect gases is:

$$(p)v \text{ constant} \propto t \quad (v)p \text{ constant} \propto t$$

$$p\,v \propto t$$

$$\frac{p\,v}{t} = \frac{p_1\,v_1}{t_1} = c = \text{constant}$$

Reducing this to a concrete form of unit value by substituting 0 degrees centigrade one cubic foot of dry air at the sea level, we have

$$\frac{p_0\,v_0}{t_0} = \frac{14.7 \times 144 \times 12.38}{460.66+32} = 53.21$$

$$\text{Then } \frac{p\,v}{t} = c\,p\,v = 53.21 \times t$$

This is for isothermal compression. For adiabatic compression in which the temperature is allowed to increase. The specific heats must be introduced and it can be shown mathematically that

$$p\,v = p_1^{\gamma}\,v_1^{\gamma} = \text{constant}$$

and by eliminaiing p by using $p\,v$ constant $\times\ t$ we have

$$\frac{t}{t_1}=\left(\frac{v_1}{v}\right)^{\gamma-1} \text{ and } \left(\frac{p}{p_1}\right)^{\frac{\gamma-1}{\gamma}}$$

in which $\gamma=\frac{C_p}{C_v}$ and is the ratio of the specific heats for a perfect gas, v_1 p_1 t_1 being other values taken anywhere.

As you know, air is not a perfect gas, being on the contrary a mechanical mixture, but for all intents and purposes we may use the formulae given:

$$\text{For air } \gamma=\frac{0.2375}{0.1689}=1.406$$

So much for the fundamental principles governing air compressing, but how is this knowledge applied?

For low pressures, centrifugal or rotary blowers are frequently employed. There are also several forms of hydraulic compressors depending on the pressure imposed by a column of falling water. The air being collected at the top carried down with the water and released into a receiver at the bottom. These all serve a useful purpose. However, for present purposes it is better to confine ourselves to the simple compressor engine. In this we have a cylinder and a reciprocating piston and for the moment we will avoid all details such as valves, regulators and speed. As we move the piston forward the inlet valves open and air continues to enter the cylinders under atmospheric pressure until the piston comes to rest at the end of the stroke when the inlet valves close, leaving the cylinder full of air at 15 pounds pressure and normal temperature. This is the free air capacity of the cylinder. Immediately the piston begins to return, the pressure and temperature begins to increase and continues to rise until the pressure is sufficient to raise the discharge valves. When the piston is moved forward forcing the air into the receiver at a constant pressure until the end of the stroke is reached we thus have a complete stroke divided into three portions—the intake, the compression and the expulsion.

If we refer to the diagram of this cycle, which in a general way resembles the indicator diagram of a steam engine, we notice that the actual work done in compression consists of two portions. A triangular shape section (the actual compression), and a rectangular shape section (the expulsion). Mathematically this can be shown equal to

$$W=3\,V_m\,p_m\left[1-\left(\frac{p_n}{p_m}\right)^{\frac{1}{3}}\right]$$

in which V_m equals volume delivered to receiver; p_m equals receiver pressure and p_n equals initial pressure of the air drawn in the cylinder. As it is a little bit inconvenient to use this formula in each case the following table will prove of service and is near enough for ordinary working purposes.

TABLE I.

HORSE POWER DEVELOPED TO COMPRESS 100 CUBIC FEET OF FREE AIR FROM ATMOSPHERE TO VARIOUS PRESSURES.

Gauge pressure lbs. per sq. in.	One-stage Comp. D. H. P.	Gauge pressure lbs.	Two-stage Comp. D. H. P.	Four-stage Comp. D. H. P.
10	3.60	60	11.70	10.80
15	5.03	80	13.70	12.50
20	6.28	100	15.40	14.20
25	7.42	200	21.20	18.75
30	8.47	300	24.50	21.80
35	9.42	400	27.70	24.00
40	10.30	500	29.75	25.90
45	11.14	600	31.70	27.50
50	11.90	700	33.50	28.90
55	12.67	800	34.90	30.00
60	13.41	900	36.30	31.00
70	14.72	1000	37.80	31.80
80	15.94	1200	39.70	33.30
90	17.06	1600	43.00	35.65
100	18.15	2000	45.50	37.80
		2500		39.06
		3000		40.15

The result for two and four-stage compression can be determined by using this formula, introducing, however, the condition of intercooling which will be explained later.

The work of compression in the first cylinder would be calculated and the air at this high pressure would be regarded as the entering air for the second compression and so on.

The work of compressing a given weight of air can also be obtained by using the following formula:

$$\text{Total work} \frac{(\text{number of stages})\, n}{n-1} \left(\text{constant}\right)\left(\begin{matrix}\text{absolute}\\ \text{temperature}\end{matrix}\right)\left[\left(\begin{matrix}\text{final pressure}\\ \text{initial pressure}\end{matrix}\right)^{\frac{n-1}{(\text{No. of stages})\, n}} - 1\right]$$

$$n = 1.406$$

In determining the efficiency of compressors the usual practice is to divide the total isothermal work by the total work of adiabatic compression using the same initial pressures, temperatures and final pressure for both cases. Absolute temperature at the end of the pressure may be found by using the following formula:

$$T_m = T_n \left(\frac{p_m}{p_n}\right)^{\frac{1}{3}}$$

p_m = final pressure
p_n = initial "

In this T_m represents the temperature of the air the instant compression is completed while T_n represents some final temperature which is reached after the air has passed through the receiver or is the temperature at which it would be used.

There is generally a drop in temperature, because the air is seldom used immediately upon compression and is allowed to collect in the receiver. It is also carried in the pipe line for some distance and this exposure allows the compression heat to be largely radiated. The mechanical equivalent of this lost heat is actual work lost and naturally reduces the efficiency of the equipment. This heat can be returned to the air by means of special reheaters, but this point will be discussed later.

To further illustrate the formula just mentioned the following table is of interest and shows the heat produced by compression of air starting with one atmospheric pressure and running to a pressure of 352 pounds per square inch gauge pressure. This table runs through the range of low, medium and high pressures. If the last column is examined it will be seen that the temperature for 100 lbs. is about 390 degrees which is hotter than steam at 205 pounds pressure. This heat accumulates and makes some method of removing the heat from the cylinder absolutely essential. In the earlier form of compressors this was accomplished by spraying water into the cylinders and depending upon this water to absorb the heat, the water afterwards being expelled by the piston in its advancing movement. Other forms employed cylinders in which a considerable amount of water was allowed to remain all the time, the water passes out of the valves with the air and wasting away.

Neither of these forms could satisfactorily meet the existing conditions for high pressures and they have been abandoned in favor of a system of careful jacketing or surrounding the cylinders with water on the outside and having one, two or three stages according to the final pressure—the air passing from one cylinder to a special cooling apparatus entering the second cylinder at a lower temperature—being compressed again and so on. By this means air may be delivered cooler at a final pressure of 2,000 or 3,000 pounds per sq. in. and a temperature not over 200 degrees.

Another very serious objection to the types employing water in the cylinders was the limitation of speed at which the piston could travel. It will be seen that the large quantity of water in the cylinder made the compressor practically a water pump and the limitations which apply to any form of pump were imposed on such compressors.

The forms employing jacket cooling allow a much higher piston speed which reduces the size of cylinder and naturally the size of the compressor for a given output. This makes reductions in cost all along the line and is to-day the established practice in this country.

For pressures exceeding 100 pounds, compound or two cylinder compressors are absolutely necessary, the air in the first cylinder being raised to possibly 30 pounds, the temperature not exceeding 260° provided the cylinder is jacketed throughout.

Compounding does not result in any material economy unless the air is thoroughly cooled between the stages. Hot air in the cylinder means a reduction in the efficiency of the machine because there is not sufficient time during the stroke to thoroughly cool the air. The curves shown (Saunder's curves) afford an idea for adiabatic and isothermal compression of the volumne; the temperatures in each case with 0°, 60° and 100° F. as the initial temperatures and the pressures.

We have already sub-divided compressors into low, medium and high pressure. For general purposes we may further specify the first to mean from 5 to 50 pounds

—the second from 50 to 500 pounds, the third from 500 to 5,000 pounds pressure per sq. in.

The first class covers all forms of blowing engines used in blast furnaces, which generally speaking, are slow speed Corliss type, with large air cylinders and some form of simple flap valve. They are universally of the single compression type and generally no attempt is made to cool the air.

The second or medium class includes by all odds, the greater portion of the machinery used at the present time. In this are all of the compressors operating coal cutters, rock drills, machine tools of any sort, hammers, chippers, riveters, etc., air lifts, air hoists, etc. Single, double or compound compressors are customary in this class.

The third class is employed almost exclusively for the operation of the mine locomotives, yard engines and street railways, also for the operation of liquid air apparatus. Compressors in this class are invariably three or four stage machines and the types here illustrated is one which is used to supply the compression or for operating the 28th and 29th Street crosstown line in New York city. This is the largest high pressure compressor in the world.

This compressor is a vertical compound engine four-stage machine with steam cylinders 32″ and 68″ and 60″ stroke. At a speed of 40 revolutions per minute, it has a horse power of a little over 1,000. The shaft is 22″ in dia. and the fly wheel 22 ft. with a weight of 60 tons. The compressor portion consists of four cylinders, the low pressure having a diameter of 46″, 1st intermediate 24″, 2d intermediate 14″ and high pressure 6″. All single acting with a stroke of 60″. Free air capacity per revolution is 56¾ cu. ft. This gives a capacity of 2,270 cu. ft. at 40 revolutions and over 3,400 at 60 revolutions. The pressures are approximately 40, 180 and 850 and the final pressure of from 2,300 to 3,000 pounds. The engine complete on its foundations stands over 60 feet high.

It has been in daily operation since its installation and has compressed the air up as high as 3,000 pounds.

So far we have only stated the generalities of compressors. It is also advisable to look into the details of construction somewhat, to put ourselves in possession of information which will enable a wise selection to be made should problems involving the use of compressed air arise.

In the first place the cylinders of modern compressors are fairly long, the ratio of diameter to length being less than in the case of steam cylinder. They should be invariably waterjacketed throughout and *especially* in the *heads* where the greatest heat is developed and where the hot air remains in contact with the metal the longest.

The cylinders should be heavy enough to withstand with absolute certainty, the considerable strains produced by compression. The material employed in their construction should be the best possible as compressed air has a peculiar way of leaking through pores and spongy places.

Clearance should be the least possible consistent with the safety of the machine. In the case of steam engines clearance is not so serious a problem because the admission pressure balances the pressure in the clearance. With air compressors the case is altered. Assume any compressor cylinder with the piston near the end of the stroke, gradually pushing the compressed air out through the discharge valve. The end of the stroke is reached and the piston starts in the reversed direction; at this instance the discharge valve closes but there remains in the cylinder a certain volume of air, depending directly upon the clearance space, which is under a pressure slightly less than that in the cylinder. As the piston continues to move back this air expands and holds the inlet valve closed for some appreciable time, the exact length of which will depend upon the amount of contained air and the receiver pressure. Finally when the air inside is expanded to a point slightly below the atmospheric pressure the inlet valves will open and the normal operation of the compressor begin. This holding closed of the inlet has been known to reduce the efficiency as much as 10 per cent. The "wet compressors" previously mentioned reduce the clearance space to practically nil, but the disadvantages of the wet system outweigh the saving effected by no clearance.

A concrete example of this clearance loss is afforded by the following:

Suppose we allow one-half of 1 per cent. for clearance in a cylinder having a volume of 780 cu. in. in which the maximum pressure is to be 250 lbs. at the end of the

stroke. We have practically 3 to 4 cu. in. of air under a pressure of 250 pounds. As the piston returns this air expands following the piston and filling the cylinder to about 9 per cent. of the stroke which reduces the volumetric efficiency about 9 per cent. before atmospheric pressure is reached. Another factor bearing on the clearance is the air valves, both inlet and outlet, and these parts of a compressor are of far greater importance than is generally attributed to them. They are more often the cause of failure of compressors than any other one factor.

A good inlet valve must embody the following features: It must be simple and absolutely reliable. It must have ample area of opening. It must open instantly the piston changes direction and remain open through the entire stroke and close instantly at the reversal of the piston movement. To obtain the fullest volume possible it must work with the least possible expenditure of energy—it must be infallible in action; accessible for examination and free from complications likely to become deranged. A variety of inlet valves have been devised, but for purposes of explanation we may classify these under three heads.

Various *forms of poppet valves* employing gravity or springs to close them and depending upon atmospheric pressure to open them; *mechanically moved valves* made to operate by some form of direct connection with the engine movement, or some form of poppet valve which is touched off or started by some arrangement of levers or links and depends on springs to close it.

The third class is rather comprehensive and includes all special valves which are positively new, such as the Sturgeon's valve of England, etc.

Perhaps the most successful form of inlet valve so far devised is that known as the Ingersoll-Sergeant Piston Inlet, and shown in the figure. This consists of a hollow piston head connected with the outside by an extension tube, passing through a stuffing box in the back cylinder head. Each face of the piston has a circular slot concentric with the piston rod in which is placed a solid steel ring valve. These piston inlet valves and tube are carried back and forth by the piston in its movement. No springs are used and owing to the very large valve opening there is none of the throttling of the incoming air and none of the chattering and hammering so noticeable with poppet valves.

These valves give a large area of opening with a small movement of valve, thus quickly opening a large supply port enabling the compressor to run at a high speed without reducing its efficiency.

It also permits a remarkably small clearance space as it is only necessary to turn a shallow groove in the heads into which the projecting part of the inlet valve is received.

The constant inrush of cold air through the inlet tube always in one direction and the absence of springs and complications and the features above mentioned results in an increased efficiency of from 5 to 10 per cent. This arrangement also permits a most ingenious "unloading" device to be employed.

Discharge valves must differ from inlet valves because they open and close under considerable pressure. The air when ready for discharge is compressed and hence its volume is considerably less than when drawn into the cylinder. This permits a smaller valve area. They must, however, be large enough to avoid wire drawing. Discharge valves must be absolutely tight because a small leak with air under full pressure will cut down the capacity of the compressor to an alarming extent and still give no outward indication.

If operated mechanically, that is, by some rigid connection to the moving parts there is a danger of accident, should the receiver pressure suddenly drop as a result of a pipe breaking or a sudden accidental demand for air. This brings on a condition where the pressure is in the cylinder and hence on the inside of the valves is greater than that on the outside, which immediately throws a considerable strain on the valve mechanism under which some part is apt to be bent or broken. For this reason and the fact that the poppet valve is automatic in action it is the form almost universally used for discharge valves.

Pressure Regulators and devices for maintaining a constant air pressure at the point of use and devices for reducing the amount of air compressed as the demand for air decreases are essential in any compressed air installation, especially in small plants where at times all of the apparatus is idle and the next moment thrown into

operation, that is, when the small number of operating machines causes considerable fluctuation in demand for air.

Frequently this regulation is effected by allowing the air to blow off at the safety valve of the receiver when the working pressure is exceeded. This, however, is extremely wasteful and compressors depending on this system should be avoided.

Belted machines are frequently used, the belt being shifted to effect the regulation. This is a faulty system, applicable only to the very small sizes, and should not be considered.

Electric driven compressors are regulated by some form of switch controlled by the air pressure. They can be made to operate very satisfactorily, giving a close regulation.

Steam actuated compressors should have a compound regulator, that is, some form which cuts down the steam consumption when the demand for air decreases. This is usually accomplished by employing some type of throttling valve belted from the engine or attached to the receiver. This would seem like a simple matter, but many of the so-called regulators are most defective in practical operation, not responding promptly to pressure variation or possessing the fatal defect of getting out of order. These imperfect forms usually require careful watching and more or less repair. Among the many regulators the one illustrated meets the several peculiar conditions most satisfactory.

Briefly it consists of a compact cylinder connected with the receiver and engine throttle, and both ends of the air cylinder in such a manner that when the receiver pressure exceeds the set limit the cylinder discharge valves are held open so that the full pressure is on both sides of the piston holding the inlet valves tightly closed. In this way the air simply passes back and forth from one side of the cylinder to the other, the only work being that necessary to overcome the slight friction through the valves and in the delivery space. To cut down the steam consumption and prevent the engine racing, as it would with no load, the "automatic balanced throttle" closes leaving an opening just sufficient to keep engine running at such a speed that when the load again comes on there will be no shock or jar. To do this the regulator first opens the throttle, admitting more steam, and then it throws on the load. Compressors equipped with this regulator are thoroughly automatic in action and require no more attention than an electric motor.

Having discussed compression in a general way we turn to the next link in the cycle, namely, transmission.

This means the conveying of air pressure from some generating station to a more or less remote point where it is used in large units or distributed to a number of small units. The latter system resembles the water mains of a city. In either case the pipes must be employed and the size and strength must depend upon the quantity of air desired, the final pressure and the distance to which it is to be transmitted.

Among those not fully informed an idea is current that power cannot be transmitted by means of compressed air with any degree of economy. Transmission by this means is not only possible, but is being done in a large number of instances with a very satisfactory degree of economy. There are a large number of cases where the actual economy does not count because the characteristic features of compressed air are essential. This is usually the case in all construction work of a temporary character, most unfortunately it is often the case in permanent work due to an effort to economize in first cost, which, as in other engineering work frequently results in an ultimate greater expense.

In shop installations air mains are seldom over 1,000 feet long. Mining, however, affords many examples of lines from 1,000 ft. to several miles. One of the best examples of air transmission is afforded by the system of the Paris Compressed Air Co., installed under the direction of Mr. Victor Popp, the chief engineer and inventor of the company. For the details of this plant you are referred to "Compressed Air" for Sept. and Oct., 1899. The ultimate capacity of this plant will be 8,000 h. p. in four units with pipe lines or distributary mains running under ground in the great sewers and covering a large portion of the city of Paris.

Some years ago Profs. Reidler and Gutermuth made a series of experiments with this system, using lines up to 10¼ miles long. The initial pressures were about 6.9 atmospheres (about 100 pounds per sq. in.) and a velocity of about 30 feet per

second. Through an 11 inch main 600,000 cu. ft. of free air could be delivered per hour, giving a terminal pressure of 5.9 atmosphere.

The deductions from these experiments proved that power can be transmitted by compressed air within a radius of 20 miles without excessive loss of pressure, and that with pressure as low as 132 lbs. per sq. in., using a 30 inch main, the loss in a distance of 20 miles will not exceed 12 per cent., permitting a recovery of from 40 to 50 per cent. of the compressing power in the motors using cold air. With the air reheated to, say, 325° F., from 59 to 73 per cent. can be usefully recovered. This statement is made on the authority of Prof. Wm. C. Unwin, the well known English engineer.

So far no mains of this size have been employed, 12, 14 and 16 inches being maximum dimensions. But with mains of the smaller sizes in actual daily operation, transmission efficiencies of from 75 to 98 per cent. have been reached. The Nottingham Colliery, at Plymouth, Pa., which is, perhaps, the largest producing coal mine in the United States, affords another example. The line in this case is made up of 2,459 ft. of 14 in. pipe followed by 1,100 ft. of 8 in. pipe and several other long branches. The air is used to operate various pumps with a working capacity of 4,500 gallons per minute. One of these pumps, a No. 10 Knowles, is 7,000 ft. from the compressor.

We do not know the actual efficiency of this transmission system, but the equipment has effected a remarkable saving over the old steam method. About 12,000 cu. ft. of free air per minute are used in the system, the air being furnished by two Ingersoll-Sergeant Duplex Corliss Compressors, with steam cylinders 28x48" and piston inlet air cylinders 34¼x48 inches.

In considering a central compressing plant of about 12,000 cu. ft. free air capacity per minute compressing air to 100 lbs. pressure, with a properly designed and carefully constructed system of mains, a safe average will be about 1.35 cents per h. p. per hour, or $40.50 per year of 3,000 hours, delivered at motors or drills at a distance of 8,000 ft., including interest, depreciation and all expenses, although this figure has been bettered, even in smaller plants.

As in the case of electric transmission the larger the conductor within certain limits the more efficient will be the transmission system. But a point is reached, however, where the interest on the investment in the pipe line balances the saving resulting from increased efficiency.

Briefly stated the losses in a pipe line are leakage and friction. Leakages should and can be made practically nothing, although it frequently amounts to quite an item in poorly constructed piping systems.

Friction varies inversely as the diameter, directly as the square of the velocity, directly as the length and directly as the density of the air.

A general formula for calculation of

$$D = x_1 \sqrt{\frac{p_1 - p_2}{w_1 \times l}}$$

compressed air delivered in which D = cubic feet of compressed air discharged; p_1 = initial gauge pressure in lbs. per sq. in.

p_2 = terminal gauge pressure in lbs. per sq. in.

w_1 = density or weight in lbs. per cu. ft. of air at initial pressure.

l = length of pipe in feet.

x = a constant = depending on diameter, etc., and is as follows:

Diam. in inches.	Constant	Diam. in inches.	Constant.
1 =	45.3	9 =	14872
2 =	297	10 =	19480
3 =	876	11 =	24800
4 =	1856	12 =	30926
5 =	3298	13 =	37898
6 =	5273	14 =	45690
7 =	7817	15 =	54462
8 =	10900	16 =	64102

Should cu. ft. of free air be desired

$$F = W_2 \times D$$

F being equivalent free air.

W_2 density of discharge air in atmosphere = (0.068 p_2 + 1) and p_2 as before the final gauge pressure in pounds per square inch of the discharge air.

We are now on the last portion of the cycle, "The Uses of Compressed Air." While there are hundreds of special uses to which it is daily applied they may all be classed under three general headings: 1, Expansively; 2, Direct Pressure; 3, Displacement.

The first refers to its use as a thermodynamic fluid pure and simple as in engines, pumps or some modification of usual steam apparatus. The second to all cases such as rock drills, pneumatic ham-

mers, hoists, riveters, etc., and the third to pneumatic caissons and the air lift, although in this latter case expansion does come into some extent.

For expansive use we have the reversal of our original compression diagram bringing us to the condition found in the steam cylinder, although cylinder condensation and other steam difficulties are eliminated.

The formula for the work of one stroke is:

$$W_g = 3\, V_m\, p_n \left[\left[1 - \left(\frac{p_n}{p_m} \right)^{\frac{1}{3}} \right] \right]$$

W_g = total work per stroke.
V_m = volume of air per stroke.
p_m = the initial or admission gauge pressure.
t_m = the initial or admission gauge temperature.
t_n = the final or exhaust gauge pressure.

In this connection it is well to point out the economy to be effected by the use of reheaters for raising the temperature of the air just previous to using it.

Very complete and reliable tests have shown that reheating from 350 to 400° will effect an increase in volume ranging from 35 to 50% at an increased cost of coal not exceeding about 1-6 of what would be added were an equal volume of air furnished by coal used in a boiler to supply more steam for a larger compressor. These heaters are practical pieces of apparatus and cannot be too strongly advised. When properly designed they require little attention, are durable, easy to install and do not cost much.

Almost any of the practical uses of compressed air would require far more space than has been allowed the entire subject. We must therefore, content ourselves for the present with the briefest mention of the most important.

Pneumatic Tools

Are in such general use that we will only mention the weights and air consumption.

They will accomplish from two to five times the work of ordinary hand labor.

Drills range in weight from 14 to 35 pounds and drill from ¼ to 2 inches with from 3 to 4 inches feed and require pressures from 80 to 100 pounds, using from 20 to 45 cu. ft. of free air per minute.

Hammers, caulkers and chippers weigh from 8 to 24 pounds with strokes from 3 to 9 inches requiring from 15 to 20 cu. ft. of free air per minute.

Air Hoists.

Dia. Inches	Lifting Capacity lbs.	Lift ft.	Free air c. ft.	Wght. lbs.
3	400	4	1.17	125
4	720	4	2.13	150
6	1680	4	4.83	195
8	3000	4	8.67	500
12	6780	4	19.58	900
16	12060	4	34.49	1200
20	18840	4	55.60	1600
24	27120	4	80.80	2100
30	42360	4	125.00	4000

Capacities are calculated by multiplying area of cylinders by 80 lbs. air pressure and deducting 25 per cent. for friction, etc. As the friction, and all losses, especially in the larger sizes, is very much less than 25 per cent. the capacities are all safely within actual performance.

The Pneumatic Tubular Dispatch System which has been perfected by the ingenuity and persistence of Mr. B. C. Batcheller, of Philadelphia, now includes 3,000 feet of 6⅛ inch double tube in Philadelphia. In Boston and New York about 17 miles of 8⅛ inch tubes are employed. The carriers used weigh 13¾ lbs., are about 23½ inches long, and each will contain about 600 letters.

Air Brakes on trains, of which hundreds of thousands are in use, require the operation of some 30,000 air pumps of the well known direct acting type, a simple and compact form, but an extravagant user of steam.

Construction of foundations, using the pneumatic or lock caisson for which 50 lbs. may be stated as the maximum allowable pressure, the limit being set by the inability of the workmen to stand a greater pressure.

Pneumatic Locomotives for mine haulage have been in use for several years, and are to-day a standard product of all the large steam locomotive builders. They possess several features which make them ideal for mining purposes and most suitable for quite a variety of surface work, generally industrial operations, such as plantations, tunnels, powder mills, lumber yards, textile manufactories, cotton mills, storage warehouses and other places where the risk of fire resulting from spark and the freedom from other ob-

PNEUMATIC MINE LOCOMOTIVES.

MAKER	WEIGHT		CYLINDERS			AIR TANK				PRESSURES		DRIVERS	OVER-ALL DIMENSIONS			REMARKS
							SIZE									
	Drivers	Total	Diameter	Stroke	Valve	No.	Dia.	Length	Thickness Plates	Working	Stage	Diameter	Length	Width	Breadth	
Baldwin	20500	20500	9	14	Plain	3	$26\frac{1}{4}$ $26\frac{5}{16}$ $15\frac{3}{4}$	18′ $5\frac{3}{8}$″ 15′ 9″ 13′ $5\frac{3}{4}$″	$\frac{1}{2}$	100	600	28	19′ 0″	6′ 0″	5′ 0″	
Baldwin	22000	22000	5 & 8	12	Balanced pistons	3	32 32 $14\frac{1}{2}$	16 $13\frac{1}{16}$ $13\frac{1}{3}$	$\frac{5}{8}$	200	600	24				32 cars, 1 ton each up grade 166⅔
Porter		12000	6	10	Plain	2	24-36	10-12		140	300-600	20	12-14		4′ 6″	In tons of 2000 up grade 60
		22000	8	14	"	2	28-31	14-17		140	450-700	24	16-19		5′ 3″	155
		32000	10	14	"	2	31-34	15-18		140	500-700	26	17-20		5′ 5″	125

jectionable features make the compressed air locomotive a most desirable and satisfactory means of hauling.

The accompanying table gives the general dimensions of several pneumatic locomotives, which are specimens of the standard types manufactured by the Baldwin Locomotive Works and the H. K. Porter Co. This class of work calls for compressors furnishing air at from 500 to 2,000 pounds pressure.

Operation of Street Cars, two systems of which are in daily use in this country; one, the Hardie system, running in Chicago; the other, the Hoadley-Knight, recently installed by the American Air Power Co. for the Metropolitan Railway Co., of New York, and now replaced by the Hardie. The latter system has a 1,500 h. p. vertical four-stage compressor furnished by the Ingersoll-Sergeant Drill Co., the engine for which was built by the E. P. Allis Co., of Milwaukee, Wis. The system originally included 10 cars, each of which is equipped with Hoadley-Knight compressed air motors and six Mannesmann steel tubes, placed under the car seats. These latter are tested up to 5,000 pounds per sq. in., although they are never used above 3,000. This total average capacity is 45 cu. ft. capable of running the car 15 miles under favorable conditions. The compressor for this was described in the early part of this paper.

The chief use of compressed air is at the present time in the field of mining, which term includes quarrying and canal excavation. Examples of the former are too numerous and generally known to need more than the briefest mention. Some of the special machines may be of interest.

The Standard Rock Drill consists of a tripod with flexible joints, a shell in which travels the drill cylinder, a piston, piston rod, and chuck, a suitable valve, a feed screw and a suitable rotating device. This type, either in the form shown or slightly modified is used for a great many purposes. It can drill holes to 50 ft. in depth and from ½ in. to 6 in. in diameter in the hardest rock.

At present there are in use possibly 50,000 rock drills and the company with which the writer is connected is adding to this number about 3,000 each year.

The following table will be of service in calculating the amount of air necessary for operating from 1 to 40 drills with 60 lbs. pressure.

These are maximum figures, and while you may hear about new machines taking half this amount, we suggest that you figure it up for yourself, when such statements are met, and made ample allowance for the unexpected.

The Bar Channeler includes a pair of parallel bars on which is mounted a large and powerful drill. This can be moved along either by hand or automatically. This machine finds its principal use in quarries where it is employed to slot out blocks.

The Track Channeler is used principally in large quarries and for canal work, or whether it is desirable or necessary to do a large amount of face cutting, such as the sides of canals cut in rock, etc. It includes a steam boiler set on a rigid truck, a heavy form of drill with a 7 in. cylinder, suitable guides. The whole arranged to slide from one side of the truck to the other. This machine cuts a vertical or inclined slot 12 feet deep, indefinite in length, as it travels along a portable track.

Tunneling in soft or uncertain ground, formerly a most expensive and difficult operation, has been rendered a comparatively simple operation by the use of compressed air and the Greathead system of excavation and metallic lining. Perhaps, the best, certainly the most recent, example of this is afforded by the Central London Underground Railway, of London, where two tunnels, 14½ miles long, were excavated under the busiest portion of that very busy city. In this the working head is forced ahead by a series of hydraulic jacks or rams, placed at its rear, while a sufficient air pressure is maintained inside the working chamber to prevent the heading from caving. As the shield is advanced, segmental lining plates are bolted into place, forming a round pipe, which, from its shape and inherent strength, withstands the superimposed pressure. A recent and extensive example of compressed air is afforded by the Rapid Transit work now going on in New York City.

The Air Lift of raising water from the water bearing stratas of the earth is almost too simple to need explanaiion. It is, however, an important and growing use of compressed air, and should, therefore, be included in this list.

Its operation can best be described by stating that the water is raised by dis-

placement, air under sufficient pressure being conveyed through a small inner pipe to the bottom of the well, where it escapes and runs up between the outside and inside pipes, carrying water with it.

While this is not the most efficient system known, it possesses many features which make it ideal. One example only need be mentioned; a number of wells scattered over a considerable territory can be operated by this means from a convenient central plant.

Pneumatic signalling and switch operation for railways is a use of compressed air which, along with the perfection of the air brake has had more to do with the reduction in the number of railway accidents and the increase in running rates and carrying capacity of railways than, perhaps, any other one item.

In addition to these there are dozens of other applications of more or less importance, but applications where experience has shown compressed air apparatus to meet best the peculiar conditions are multiplying daily as the utility and possibilities of compressed air are better understood.

Hoisting Engines.—Assuming a working pressure of 60 lbs. at the engine and the engine running about half the time but using the full load.

DOUBLE CYLINDER HOISTING ENGINE.

Dia. of Cyl. ins.	Stroke inches	R. P. M.	Normal H. P.	Actual H. P.	Wgt. lifted single rope	C. ft of free air req'd
5	6	200	6	11.8	1000	150
6¼	8	160	12	19.8	2500	250
7	10	125	20	24.2	3500	302
8½	12	110	40	37.8	8000	476
12¼	15	100	75	89.2		1125
14	18	90	100	125.		1587

Single Cylinder engines with the same general dimensions wi l require about one-half the volume of air given above and will lift about 0.6 the weight.

Improved Reversible Pneumatic Motor.

The cut on next page illustrates a Reversible Pneumatic Motor in connection with means shown in cut, cover raised, to rotate a spindle in which may be fitted different kinds of tools used in the construction of ships, boilers, bridges, engines and other machinery. It possesses many new features which render it very desirable by manufacturers of this class of work.

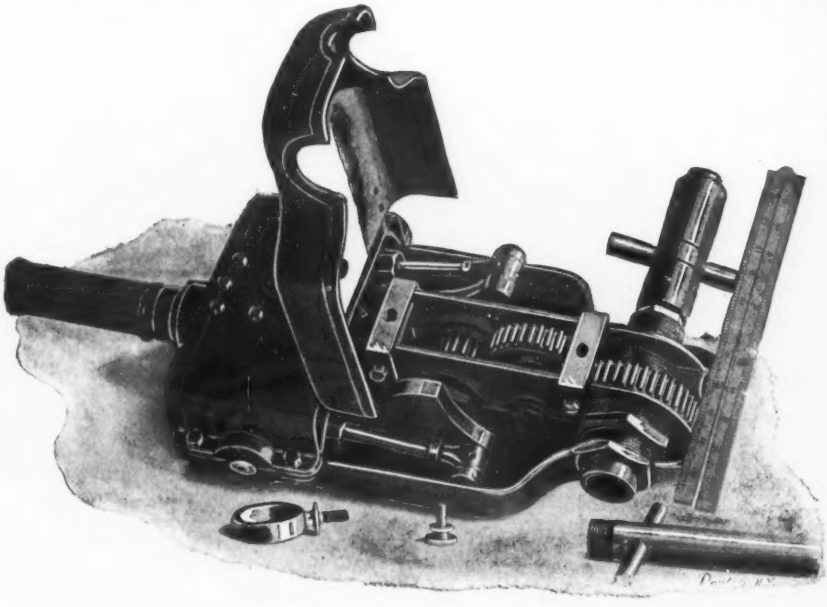
As will be seen, the spindle is through the extreme end, so it can be operated in very close quarters. The aluminum casing has a hinged lid, by raising which the machinery may be readily inspected and oiled, which later insures durability. The motor has two oscillating cylinders made of bronze brass, taking air at both ends, and the admission and exhaust are controlled by the oscillation. The trunnions have steel ferules to protect them from wear. In the main frame there are two air chests (one on each side), one for live air, the other for exhaust, and by turning the handle half way round, the functions of these chests become reversed, thereby reversing the motion and readily controlling the same. By a quarter turn of handle it stops. The air is admitted and exhausted through the handle, which also has an adjustable collar, which can be set so that the motor runs but one way only. It has a detachable handle which is used when the drill is suspended or when used for tapping and reaming.

The largest motor of this type at present built, weighs 33 lbs. and develops about two h. p. under 90 lbs. pressure, consuming about 17 cubic feet of free air per minute. The maximum speed of the drill spindle is about 200 revolutions per min-

ute under 100 lbs. pressure. The speed can be controlled by the handle or throttle to suit requirements.

This motor is not in an experimental stage; it has been in actual service for nearly two years, and has given entire satisfaction.

We believe this motor fills a long felt want, as it can be used in locomotive fire boxes to expand all the flues in the sheet



HELWIG REVERSIBLE PNEUMATIC MOTOR.

with self-feeding expanders, drilling door sheets, and holes in flanges of I-beam by setting point of feed sleeve against one flange and the drill in the other.

It has very few parts; is very compact and powerful, and is patented and manufactured by the Helwig Mfg. Co., St. Paul, Minn., U. S. A.

Notes.

The Chicago Pneumatic Tool Co., Monadnock Block, Chicago, is perfecting an electric headlight for locomotives, which it will shortly place on the market.

When air is used to drive machinery of any kind, the mechanism so employed is called a compressor; when the air is used for smelters, furnaces, ventilators, etc., the compressor is called a blowing engine.

The Chicago Pneumatic Tool Co., Chicago, is bringing out a flat piston air drill, which is said to have distinct features of merit. The air consumption is small for the power developed, and the few parts required in the flat piston type lessen weight, vibration and repairs.

Three 2¼-inch rock drills, at sixty pounds ocean level, would need a compressor, with free-air capacity of 133 cubic feet; at eighty pounds, ocean level, 168 cubic feet per minute. At 5,000 feet altitude, seventy pounds pressure, a drill would require free-air capacity of 177 cubic feet per minute.

Particulars of Lord's compressed air furnace for steam boilers have been received from the makers of the appliance, Messrs. Spurr, Inman & Co., Limited, boilermakers, of Wakefield. This invention consists of a series of troughs, gen-

erally six in number, which take the place of the ordinary grate bars in the boiler furnace.

Rippley Hardware Company, Grafton, Ill., are putting on the market an improved 5-gallon compressed air sprayer. An important feature of this device is the air compressor, by which with a minute's pumping sufficient pressure is created to discharge the entire solution in a fine mist-like spray or a continuous stream, as desired. It is fitted with a safety valve, so that only a proper pressure can be produced, thus avoiding any danger of bursting the tank. The sprayers are tested to 60 pounds pressure before shipment.

J. V. Musgrave, 33, Legrams Terrace, Listerhills, Bradford, Yorks, has taken out a patent for improvements in air humidifying apparatus which consists in employing a combined air jet and water jet with the water jet above the air jet, and fed with water by static pressure. The air jet is fed with air under considerable pressure, opens close to the water jet, and lies at such an angle thereto that the water passing from the water jet is reduced to an imponderable spray and widely diffused by the force of the current.

According to a method devised by Prof. Pictet, of Switzerland, ordinary air is drawn slowly through a condenser which is cooled by a jacket kept filled with liquid air. In the condenser the low temperature causes the oxygen to separate by gravity from the nitrogen. The former is drawn off at the bottom of the condenser and the nitrogen at the top. Any carbonic acid present will become liquefied by the cold and will accumulate at the bottom, whence it may be tapped off through pipes. The inventor claims to be able in this way to make 500,000 cubic feet of oxygen daily by the expenditure of 500 horse-power.

The New York Central & Hudson River has lately put in service at Suspension Bridge, N. Y., at the eastern end of the bridges crossing the Niagara River, a low-pressure pneumatic interlocking machine, made by the Standard Railroad Signal Company, of Troy, N. Y. The machine has 82 working levers and six spare spaces. It was at first intended that the highway crossing gates should be operated from the signal cabin, but this plan was abandoned. Suspension Bridge is the junction of three lines of the New York Central & Hudson River Railroad (from Buffalo, from Rochester and from Lewiston); and the main line of the Michigan Central, the Erie and the Lehigh Valley roads.

The idea of the bar machine in coal cutting machinery was put into practice early. Mr. F. Hurd's "Pneumatic Electric," the special feature of which was that the cables supplying the current to the motor driving the coal-cutting machine were enclosed in the iron pipes which also conveyed compressed air to the machine, and discharged it inside the case in which the working parts of the electric motor were confined. In Mr. Hurd's opinion, this plan overcame the difficulty of gas being fired by means of a spark at the commutator of the electric motor, as it maintained a pressure in the casing which prevented the gas entering and coming into contact with the sparks.

Somebody has been stuffing the editor of the New York *Times*, or perhaps, he had a bad dream. A recent editorial of our esteemed contemporary spoke about the damage that is being done to adjacent property by the blasting of the rocks in the excavation for the Rapid Transit subway, and it seriously proposed a most absurd remedy. Use no more high explosives. When the holes are drilled in the rock, turn in jets of steam to heat it and then pour in liquid air. The sudden cooling of the rock will of course crack it without any explosion. If they would only get a gallon or two of liquid air from Prof. Tripler and try it some day in a hole or two, we would like to see the fun. We cannot think, however, that any one can be found visionary or credulous enough to so try it.

Mr. W. H. Finley, principal assistant engineer of the Chicago & Northwestern Railway, has recently designed and fitted up a pneumatic tool car, from which great things are expected by the bridge and motive power men. It consists of one 15 hp. Otto gasoline engine, one 6x8 horizontal Ingersoll-Sergeant compressor, one air tank, two cooling tanks and one gasoline tank, all mounted on a flat car. There is also 600 feet of hose and piping with connections to the air tank, so that three sets

of tools can be used at once. All the tools are of the latest and largest capacity. When necessary, the machinery can be removed from the car. It is of great value in repairing bridges, and convenient for new bridge work. The engine and compressor are controlled automatically, and so the plant requires no particular attention except as to lubrication.

In a creamery at Oswego, N. Y., an experimental liquid air plant has been installed and is being used in connection with the making of butter. The plant consists of apparatus for the liquid air, an engine, a refrigerator, a cooler and a churn and separator. The liquid air was placed in a large tank and was released by valves from this tank to a generator, where the oxygen and nitrogen are separated. From here it passes to a 10 H. P. engine, which it is stated, operates satisfactorily. Before the liquid air reaches the generator, it is conducted into a large refrigerator, where the temperature is reduced to 20 degrees below zero. The exhaust from the engine, which is nearly pure oxygen, may be used in connection with the fuel. On the end of the exhaust pipe being turned into a coal stove in the room as an experiment, much heat was developed in a brief time. A small piece of live coal placed in a bucket full of coal and the exhaust turned into it very soon set the coal in a blaze.

Several underground reservoirs for the storage of compressed air in Pribram, Bohemia, have been prepared, either in disused headings or in the form of special chambers blasted out of the rock. The open extremity in each case has been closed by a dam composed of two-bricked alls, with an intervening mass of rammed concrete. Where the rock is fissured the interior of the reservoirs has been carefully plastered all over with cement mortar. No blasting operations are allowed in the vicinity of these reservoirs, owing to the risk of cracking the dams.

One example of this kind of reservoir has a cubical capacity of 5,300 cubic feet. Three other similar reservoirs are provided in the Prokop, Maria, and Stephan shafts, the air being forced in so as to develop a pressure of 4 to 5 atmospheres, and employed to work drills, pneumatic winches and duplex pumps.

A patent was granted recently for an improvement in pneumatic hammers. The novelty of the invention consists of a supplementary supply port, by means of which admission is prolonged, and air is continuously admitted in a small quantity during expansion. Also this supplementary port serves to bring the pressure more gradually on the bottom of the piston on the back stroke. Thus the force of the blow is increased, and the recoil of the returning piston is lessened, rendering the hammer easier to hold.

If on the forward stroke, the piston is past cut-off, but air is being admitted similarly, thus keeping up a greater pressure during expansion.

Although recently patented, this device has been on the market for some time and has proved exceedingly successful on all work, such as flue beading, medium weight caulking, and machine shop chipping. The patent was issued to C. H. Johnson, of Chicago, and is made use of on a hammer which is one of the products of the Railway Supply Co. of Chicago, formerly the Q. & C. Co.

Compressed air prevented the suffocation of 35 men shut up in the New York Rapid Transit tunnel at 181st street, by a dynamite explosion which wrecked the hoisting gear in the shaft. The shaft at this point is 131 feet deep and the tunnel only extended about half a city block each way from the shaft. At noon, on March 21, about 50 lbs. of dynamite exploded from some unknown cause in this short section of tunnel, and one of the hoisting cages was wrecked and the other was so damaged that it would not work for some time. The thick fumes of the exploded dynamite were suffocating the 35 men then in the tunnel, and the prompt action of Engineer John G. Mullen, who at once turned on the air-compressors at full speed, alone saved them from death. The men lay for over half an hour face down in the tunnel and breathed the fresh air sent them by Engineer Mullen, while the damaged cage was being repaired. When the men were finally brought to the surface it was found that nearly all of them were burned about the face and hands, and three were bleeding profusely from lacerated wounds. Most of the clothing worn by these men was torn into shreds.

The presence of mind and the quick action of Engineer Mullen alone saved the 35 men from death.

Dr. Carl Barnes, of Chicago, has recently made some experiments with liquid air as an agent in the cremation of the human body. A number of experiments in that direction have been made heretofore, but without success. Although a steel pen, when ignited in contact with the fluid will burn and even evaporate, animal tissue is not readily consumed. Dr. Barnes claims that, after frequent experiments, he prepared a piece of beef with a simple chemical application, which he thought would aid the combustion, and the nature of which he does not divulge, but when so treated the meat was consumed in an open furnace in a few minutes, leaving only a fine ash, and producing almost no odor. Experiments with parts of cadavers, obtained from the dissecting rooms of medical colleges, proved equally successful. The doctor thinks that in a closed furnace a human body would be entirely consumed in from fifteen to twenty minutes. In the ordinary crematories it requires three hours, and it is necessary to fire up the furnaces some hours before in order to obtain the necessary high temperature. The liquid air crematory of the future will be ready to begin any moment.

In the interesting paper, recently read by Mr. Pressinger before the New York Railroad Club, he advocated the placing of the air receiver in as warm a place as possible. As to that, there may be something said on the other side. If the air is compressed in a single stage compressor, and if the compressor is run up to nearly its full capacity, the air in the receiver will be so hot that the temperature of the air surrounding the receiver will not make any perceptible difference. When air receivers have exploded, by the ignition of the mixture of air and volatilized oil within, it would certainly have been better if they had not been so hot. The only reason that can be advanced for keeping the receiver hot is that the volume of air may be as great as possible when it is used, but as the air usually has to travel a considerable distance after leaving the receiver, so that it gets down to normal temperature before it does its work, the temperature of the receiver has no ultimate effect on the efficiency. If the air in passing through the receiver is hot, it will not give up much of its moisture, but if the receiver can be cold, and if the air in passing through it at its highest pressure is also cold, much of the moisture in the air will be left in the receiver, and there will be much less "freezing up" of the air in working.

Armand Gautier, the distinguished Professor of Chemistry in the Paris School of Medicine, has lately added yet another substance to the list of aerial rarities. This is the element hydrogen, and his announcement that it is to be found in a free state—that is, uncombined with any other element—in our atmosphere, is one that will arouse a large amount of interest both in chemical and astronomical circles.

Hydrogen is one of the most common, as it is the lightest, of the elements. It forms one of the two gases composing water, and it is the gas which, blazing in the sun, literally makes the world go round. The demonstration of its presence in the air in a free state is the outcome of a long series of researches on the part of M. Gautier. He found hydrogen existing to the extent of 17 parts in 100,000 in the air of the high Pyrenees. On the Brittany coast, forty kilometers from land, and ensconced in a lighthouse, M. Gautier demonstrated that as much as 2 volumes of hydrogen in 10,000 of air could be detected, and possibly this latter computation represents the normal amount which the atmosphere contains. The interest attaching to this discovery may be diversely interpreted. For example, if the quantity of hydrogen in our air happened, through some disturbance or other, to be enormously increased, ructions of a comical kind might ensue, for hydrogen and oxygen have a particular chemical fancy for union, and when they do unite the result is "explosions and alarms" and the formation of water. This lecture-room experiment, however, is not likely to be produced in the theatre of the universe, for the reason that the hydrogen appears to be in a dreadful hurry to leave our earth's air shell. M. Gautier thinks the atoms of hydrogen tend to fly away from us at the rate of over seven miles a second, and that there is no danger of any terrestrial accumulation to be apprehended. His notion is that the hydrogen is begotten of the earth through chemical action taking place in our crust.

A small water-works system was put in operation at Pratt City, Ala., about Dec. 1, 1900. The works are owned by the city and were built by contract, with Alber & Byrne, of Birmingham, as engineers. The supply is drawn from two 8-inch wells, sunk in the rock, one being 354 and the other 259 feet deep. Each well is provided with an air lift pump, the water pipe being 4 inches and the air pipe 1¼ inches in diameter. The air pipe goes down 200 feet, and is designed to give 50 per cent. submergence. The air compressor is designed to lift 300 gallons of water per minute, and 306 gallons have been raised from both wells.

The air lifts discharge into a 100,000-gallon reservoir, roofed with a wooden frame and steel covering. Two 500,000-gallon pumps force water to a 12x100-foot stand-pipe, or directly to the mains, if desired. There are nearly three miles of 8 to 4-inch cast iron mains and 32 two-way hydrants. All the pumping machinery was supplied by the Smith-Vaile Co. Mr. G. W. Donaldson, City Clerk, will act as superintendent of the works. Mr. E. T. Hudall is Mayor.

An interesting little plant was started at Elberton, Ga., about a year ago, but has not been completed, owing to the failure of the people to vote the necessary bonds. Some springs were developed by excavating and walling up a reservoir about 40x45 feet in plan, with 12 feet of water. Portions of the reservoir bottom where rock was not reached are covered with 16 inches of concrete. The side walls are of rubble, 18 inches thick at the top and 30 inches at the base. The reservoir is covered with a wooden frame and shingle roof.

Connected with the reservoir is a small power house, 17x19½ feet, outside dimensions. Here an electric pump, with a capacity of 300 gallons a minute, will be placed. The current to drive the pump will be supplied from the city lighting station, some three or four miles distant, where it is generated by water power. Alber & Byrne were also the engineers for this plant.

Trotwood is a small unincorporated village in Montgomery County, Ohio, a few miles northwest of Dayton, with a population of 214.

A very disastrous fire in 1898 was responsible for the installation of a water-works in this village, the smallest in Ohio to be so provided. The plant was completed in 1899, and was intended at first for fire protection, only, but now the water is being used for general purposes.

The water supply is secured from two 8-inch wells, driven 26 feet through clay and hardpan into a bed of gravel. The water stands in the wells 12 feet below the surface, and the level was lowered but little by pumping at the rate of 120 gallons per minute. The water is pumped direct from the wells to a horizontal steel tank by a vertical duplex power pump, run by a gasoline engine. The tank, engine, pump and wells are all a neat stone building, situated at the edge of the village.

The pump was made by C. O. Lucas, of Greenville, Ohio, and is fitted with a device by which a certain amount of air can be pumped with the water to the tank, and from there it is forced by air pressure under through the mains when the pump is not running. The pump is double-acting with 6x12-inch cylinders, and has a capacity of 175,000 gallons in 24 hours, at a pressure of from 40 to 80 lbs., the limits allowed in the pressure tank. The tank is 24 feet long, 5 feet in diameter, and holds 5,000 gallons. It is fitted with a blow-off cock set for a maximum pressure of 80 lbs.

The pressure in the tank is run up to 80 lbs., and the pump then stopped and the pressure allowed to fall to 40 lbs., before pumping again. On account of the few connections to the mains the pump operates not oftener than once a day, and then only for a short time.

This is the only case in Ohio where the compressed air system is used in a public water supply, though several private institutions have made use of it. This community has supplied itself with an efficient fire protection, together with all the advantages of a public supply, at a per capita cost much below the average for this section, and has furnished an example which might be copied by many other small places to good advantage.

BENJ. H. FLYNN.*

* Engineer Ohio State Board of Health, Columbus, O.

Has it been demonstrated that it is not practicable to use air drills except in hard ground?

If one were contemplating the running of 800 to 1,000 feet of tunnel along a

partly decomposed quartz ledge, would it be advisable to use a small air drill—size of tunnel, 6x8 feet?

If the 5-foot holes would shake the ground too much, necessitating timbering, would it pay to use an air drill and put in 30-inch to 36-inch holes?

Have stoping drills been used to run a drift, and, if so, what progress could be made in moderately hard rock?

Information on this subject will be much appreciated. W. M.

San Francisco, Cal.

The following is in answer to the above:

If ground is hard enough to drill, power drills can be used to advantage. If the ground is not very hard, do not put in as many holes. A tunnel 6x8 certainly could be run with power drills to a profit over hand labor. He must expect some backs with an 800-foot or 1,000-foot tunnel, and is it not likely that in depth his ledge will get hard? Yes; we stope, raise and drift, often with the same drill, 2¼" Giant. When we first put in air drills we used nothing but the 3⅛". We did not stope much with them—mostly drifting and raising. Now we have no 3⅛" in use in the mine, 2¾" being the largest. We now use the 2¼" for nearly everything. We have concluded that most people are given to the use of too heavy drills. We are satisfied that we can drill almost any kind of ground with a 2¾" drill. We use water with all of our machines, which is of great help in every way. Twelve hundred feet of our present shaft was a raise; we cut down the raise to make a 12-foot wide shaft; most of the cutting down was done with a 2¼" Giant drill, and frequently most of the five or six holes were in hard greenstone. So we proved we could drill nearly everything with a light drill (100 pounds).

With our 2¾" and 3⅛" drills we have two men; with the 2¼" only one in any position. The total cost of a drift we ran, both with 3⅛" and 2¼" drills, also the cost of a hard greenstone crosscut with a 2¼" drill, is appended. It is to be noted that the 2¼" drill is the one we stope with; we only use the 2¾" in drifting and raising:

	Feet run in each month.	Cost per foot.	Drill.
Drift.	57	$3.87	3⅛"
"	40	4.57	3⅛"
"	60	4.26	2¾"
"	18	4.36	2¼"
Crosscut in green stone.	.36	4.00	2¼"
Drift.....	.17	3.38	2¼"

The above is the whole expense per foot of drift, labor, materials, caring dirt. In some places the drift was very hard, but always a wall to break to.

The labor of breaking the ground alone by contract, single or double-hand, would in no case have been taken for less than $5, and much of it for not less than $10 per foot. L. B. J.

Forbestown, Cal.

Mining and Scientific Press.

COMMUNICATIONS.

Under this heading will be published inquiries addressed to the Editor of COMPRESSED AIR. We wish to encourage our readers in the practice of making inquiries and expressing opinions.

We request that the rules governing such correspondence will be observed, viz.: all communications should be written on one side of the paper only; they should be short and to the point.

Editor Compressed Air:—

Could you kindly show me how to use compressed air for cooling water, butter, etc.? I have two air compressors—one, at least, always in use. Could I do it with ammonia or chemicals, or would simple expansion do it, and can it be done cheaply? It would be a great boon to us to cool off our water and stuff during the hot weather soon to come along, and oblige. Yours truly,

WALTER E. KOCH.

I find your magazine very useful.

Answer.

Answering your letter of the 30th ultimo, compressed air may be used for cooling provided you have an engine, pump, or other device near the point where the cooling is to be effected, the exhaust being used for cooling purposes. It will not pay you to compress air for the purpose of getting its cooling effects through expansion, unless you can utilize the power developed during expansion. If the machines which use air are in the mines, and you wish to do the cooling at the surface, it will not be practical, and we would advise the usual methods of refrigeration; but if you can concentrate your air engine and your cooling plant you should then be able to cool very economically by compressed air. We will be very glad to have any further particulars of your work, and also to answer any questions you may ask.—EDITOR.

Philadelphia, April 4, 1901.

Gentlemen:—

Owing to the steadily increasing demand for our tools we have found it necessary to largely increase our shop, so that we now have a frontage on Ridge avenue, Eleventh and Noble streets, and for greater convenience and larger offices will remove on April 10th from the present address to 1038 Ridge avenue, corner of Noble street, where we shall be glad to receive our friends and give all orders our careful and prompt attention.

Soliciting a continuation of your valued favors, we remain,

Yours respectfully,

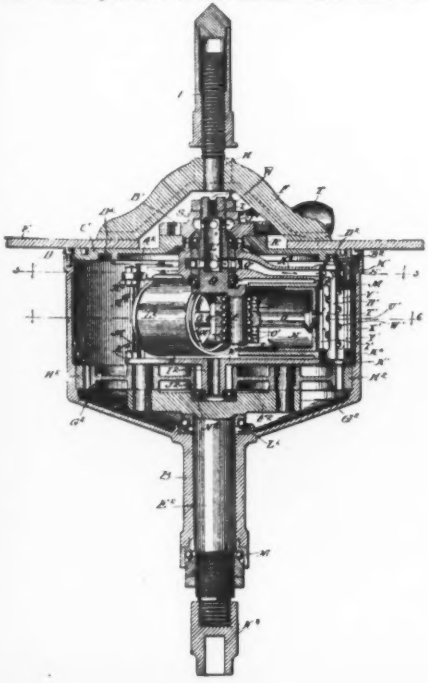
PHILADELPHIA PNEUMATIC TOOL COMPANY.

U.S. PATENTS GRANTED MAR., 1901.

Specially prepared for COMPRESSED AIR.

669,069. ENGINE. Joseph Boyer, St. Louis, Mo. Filed May 4, 1898. Serial No. 679,696.

An engine, the combination of a rotary frame, a plurality of cylinders carried thereby and having their piston-rods connected to a fixed pivot eccentric to the axis of the frame and cam-operated valves at the outer ends of said cylinders for controlling the admission and exhaust of the motive fluid to and from the outer ends of the cylinders behind their pistons.



669,118. AIR-COMPRESSOR. Franz J. A. Kindermann, Melbourne, Victoria. Filed Oct. 27, 1900. Serial No. 34,593.

An air-compressor comprising an outer cylinder having a valve for the inlet of air into its chamber, an inner double cylinder with a cooling-space between the inner and outer walls thereof, a piston within the innermost cylinder and connected with the outer cylinder, valve communication between the chambers of outer cylinder and innermost cylinder and an outlet-pipe leading from the innermost cylinder.

An air compressor comprising cylinder 1 having valve 9 at its base, a double cylinder 11 and 4 with a cooling-space between the walls thereof, a piston in the cylinder 4 connected by rod to cylinder 1, a valve communication between cylinders 1 and 4, a chamber 20, a valve communication between said chamber and cylinder 4, and an outlet-pipe from said chamber.

An air-compressor comprising cylinder 1 recessed at its base and having leather ring 9 projecting into said recess and held in position by ring 10, said cylinder being closed at its top by cap 2, a double cylinder 11 and 4 with a jacketing-space between, the cylinder 11 being of slightly less diameter than the cylinder 1 and being closed by cover 12 carrying valve 13 which opens into cylinder 4, a piston 5 in the cylinder 4 having rod 3 pass-

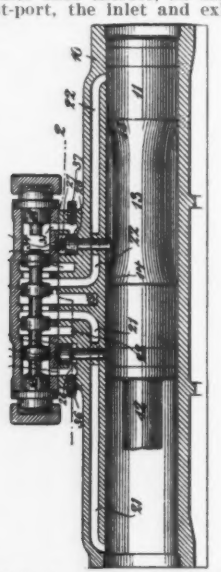
ing through cover 12 of cylinder 11 and having stop 6 and nut 8 for securing it to cap 2 of cylinder 1, a block 17 which receives the base of the double cylinder 11 and 4 valves 21, 22, 23, 24 in the said block, a base-piece 19 having chamber 20, and an outlet-pipe 27 from same.

An air-compressor comprising cylinder 1 recessed at its base and having leather ring 9 projecting into said recess and held in position by ring 10, said cylinder being closed at its top by cap 2, a double cylinder 11 and 4, with a jacketing-space 28 between, the cylinder 11 being of slightly less diameter than the cylinder 1 and being closed by cover 12 carrying valve 13 which opens into cylinder 4, a piston 5 in the cylinder 4 having rod 3 passing through cover 12 of cylinder 11 and having stop 6 and nut 8 for securing it to cap 2 of cylinder 1, a block 17 which receives the base of the double cylinder 11 and 4, a valve 21, 22, 23, 24 in the said block, a base-piece 19 having chamber 20, and an outlet-pipe 27 from same, a short inlet-pipe 30 set in block 17 and entering jacketing-space 28, and long outlet-pipe set in block 17 and rising to near top of jacketing-space 28.

669,140. PRODUCTION OF COMPRESSED GAS. Wenzl Knapp, Hamburg, Germany. Filed Sept. 7, 1899. Serial No. 729,688.

669,316. PRESSURE-ACTUATED VALVE FOR ROCK-DRILLS. Robert L. Ambrose, Tarrytown, N. Y., assignor to Rand Drill Company, New York, N. Y. Filed April 19, 1900. Serial No. 13,443.

A rock-drill, the combination with a cylinder having distributing-ports leading to and from opposite ends thereof, an inlet-port and an exhaust-port, the inlet and exhaust ports



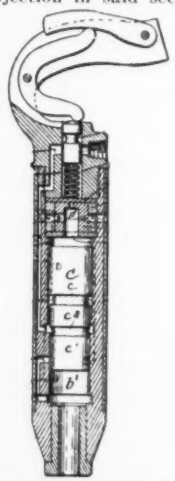
being contained within the cylinder-casing but out of communication with the interior of the said cylinder, pressure-chambers arranged at opposite ends of the said distributing-valve, each of the said chambers having a port leading to exhaust, two independent primary valves for said ports arranged in the cylinder-casing and projecting into the interior of the said cylinder, and a reciprocating piston having a reduced central shouldered portion, said primary valves arranged at such a point in the cylinder as to be always covered by the piston during its movements and to be operated by engagement with the central shouldered portion thereof.

669,485. PNEUMATIC-DESPATCH-TUBE SYSTEM. Albert W. Pearsall, Mount Vernon, N. Y., assignor to the Pearsall Pneumatic Tube and Power Co., New York, N. Y. Filed Oct. 3, 1900. Serial No. 31,863.

669,500. PNEUMATIC STRAW-STACKER. John M. Andrews, Andrews, Tenn. Filed June 20, 1900. Serial No. 20,992.

670,645. PNEUMATIC TOOL. William H. Soley, Philadelphia, Pa., assignor of one-half to George A. Dallett, same place, and Thomas H. Dallett, Cheyney, Pa., composing the firm of Thomas H. Dallett & Company. Filed Aug. 5, 1899. Serial No. 726,267.

A pneumatic tool, the combination of a case provided with a chamber, a piston in said chamber, a second chamber in said casing above said piston-chamber, a valve-casing having a projection in said second chamber,

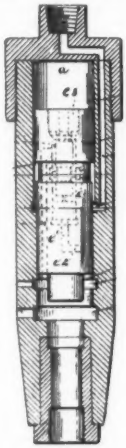


a rotary valve in said case having a cut-away portion forming a chamber in which said projection rests, said valve having its axis of rotation extending longitudinally of the tool, connection between a source of pressure-supply and said piston-chamber controlled by said valve.

670,646. PNEUMATIC TOOL. William H. Soley, Philadelphia, Pa., assignor of one-half to George A. Dallett, same place, and Thomas H. Dallett, Cheyney, Pa., comprising the firm of Thomas H. Dallett & Company. Filed May 3, 1900. Serial No. 15,327.

A pneumatic tool, in combination, a casing provided with a chamber, a shouldered piston in said chamber, a constant source of pressure-supply in said chamber below said shoulder, a valve-chamber formed in the piston, a passage from said valve-chamber through the piston to the opposite side of said shoulder, a

passage from the constant air-supply to said valve-chamber and a vertically-reciprocating valve in said valve-chamber and a longitudinal passage from the lower end of said valve-

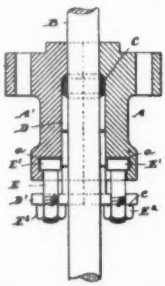


chamber opening into the piston-chamber above the lower end of said piston and an exhaust-passage from the piston-chamber above its lower end.

670,700. PNEUMATIC OR BELLOWS FOR MUSICAL INSTRUMENTS. Theodore P. Brown, Worcester, Mass. Filed Dec. 28, 1900. Serial No. 41,410.

670,750. ROCK-DRILL. Warren Wood, Paterson, N. J. Filed Jan. 15, 1901. Serial No. 43,367.

A rock-drill, a cylinder-head, a gland fitting therein and having a flange, holding-bolts securing the gland to the head, inwardly-opening recesses in the latter receiving the heads of said bolts, the body portions thereof lying



in slots opening into said recesses and extending axially of said head through said flange and receiving nuts on their outer ends, whereby the heads of said bolts are locked in said recesses by said gland.

A cylinder-head, an elastic packing and a gland therein, a flange on the latter, and bolts received in said head and extending through said flange, in combination with ridges on said flange adjacent to said bolts, and nuts matching to the bolts and having grooves on their bearing-faces adapted to engage with said ridges, whereby said nuts are held against accidental loosening.

670,760. AIR-GUN. Frederick F. Bennett, Plymouth, Mich., assignor to the Daisy Manufacturing Company, same place. Filed Jan. 23, 1901. Serial No. 44,417.

670,807. AIR-SHIP. Ole Olsen, Oakland, Cal. Filed Mar. 23, 1900. Serial No. 9,847.

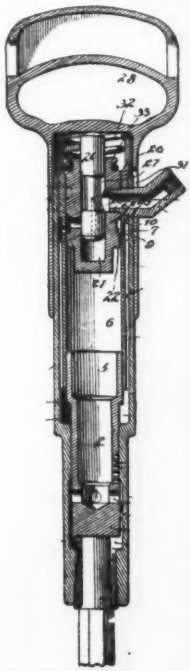
670,810. STEAM-ENGINE FOR AIR-COMPRESSORS. Gustav B. Petsche, Philadelphia, Pa., assignor to the Southwark Foundry & Machine Company, same place. Filed July 31, 1897. Serial No. 646,636.

670,866. PNEUMATIC TIRE. Pardon W. Tillinghast, Edgewood, R. I. Filed April 24, 1897. Serial No. 633,798.

670,901. AIR-BRAKE. Frank Linee, Grand Rapids, Mich., assignor of one-half to Jas. Mathie, same place. Filed Feb. 23, 1900. Serial No. 6,215.

669,599. PNEUMATIC HAMMER. Charles H. Shaw, Denver, Colo. Filed Sept. 29, 1900. Serial No. 31,527.

A device of the class described, the combination of a casing having exhaust and supply ports, and a hollow reciprocating plunger, provided near its outer end with large ports



adapted to register alternately with the supply and exhaust ports of the casing, said plunger being also provided with a longitudinally-disposed series of small ports adapted to register with the supply-port of the casing before the large ports of the hammer, whereby the length of the stroke of the hammer and

the force of the blow may be controlled by regulating the admission of the compressed air.

A device of the class described, the combination of a main casing having a longitudinal air-passage and provided with an exhaust-port, a reciprocating plunger, a valve-casing communicating with the air-passage, a valve arranged within the valve-casing, a nipple extending into the main casing and communicating with the valve-casing, a handle having a sleeve arranged on the main casing and provided with a slot receiving the nipple, and a spring for cushioning the handle.

669,606. PNEUMATIC TIRE. Bacon Wakeman Fairfield, Conn. Filed Dec. 23, 1899. Serial No. 741,488.

669,853. AIR-COMPRESSING OR BLOWING ENGINE. Gustav B. Petsche, Philadelphia, Pa., assignor to the Southwark Foundry & Machine Company, same place. Original application filed July 31, 1897. Serial No. 646,636. Divided and this application filed Feb. 1, 1900. Serial No. 3,614.

669,888. RECEIVING MECHANISM FOR TUBULAR TRANSIT SYSTEMS. Washington A. H. Bogardus, New York, N. Y. Filed July 10, 1900. Serial No. 23,089.

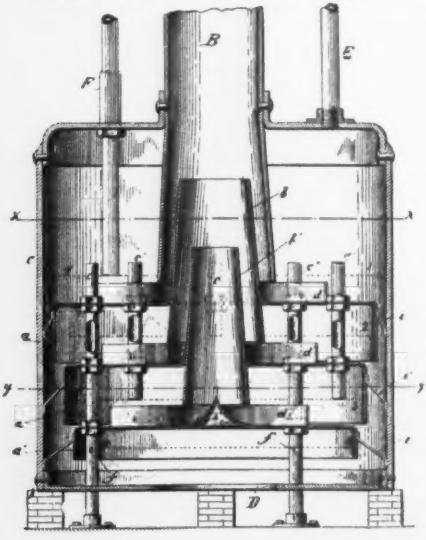
669,889. PNEUMATIC TRANSIT APPARATUS. Washington A. H. Bogardus, New York, N. Y. Filed Aug. 10, 1900. Serial No. 26,493.

669,890. CARRIER FOR TUBULAR DESPATCH SYSTEMS. Washington A. H. Bogardus, New York, N. Y. Filed Aug. 10, 1900. Serial No. 26,494.

669,891. RECEIVING APPARATUS FOR TUBULAR TRANSIT SYSTEMS. Washington A. H. Bogardus, New York, N. Y. Filed Oct. 23, 1900. Serial No. 34,003.

669,892. TUBULAR TRANSIT APPARATUS. Washington A. H. Bogardus, New York, N. Y. Filed Oct. 23, 1900. Serial No. 34,004.

669,995. HYDRAULIC AIR-COMPRESSING APPARATUS. William J. Linton, Woodstock, Canada, assignor to John A. Inslee, St. Louis, Mo. Filed Aug. 4, 1899. Serial No. 726,145.



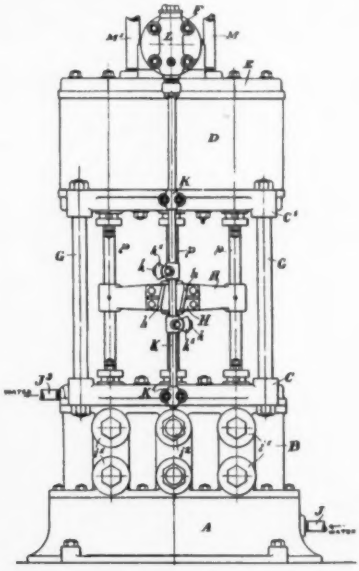
An air-compressor in which a body of water flowing first downwardly and then upwardly is used as the compressing agent, means for introducing air into the descending body of water, means for subdividing the said descending body of water and intermingled air before the separation of air therefrom, separate means for effecting the separation of the air from each of the subdivided portions of water, and means for conducting the air to any desired point or points of distribution.

A hydraulic air-compressor, the combination of two or more separating-chambers to each of which a portion only of the water flowing through the compressor is conducted.

670,000. AIR-COMPRESSOR. Frank H. Merrill, Plainfield, N. J. Filed Mar. 30, 1900. Serial No. 10,152.

An air-compressor composed of three steam-cylinders and three air-cylinders, and steam and air pistons therein having a common connection so as to move together, both said steam and air cylinders being compounded and consisting of one high-pressure and two low-pressure cylinders.

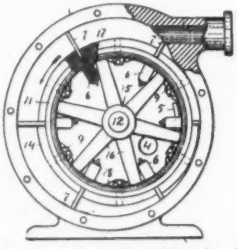
An air-compressor composed of three steam cylinders and pistons and three air cylinders and pistons arranged oppositely in pairs, each



pair being in line and consisting of one air and one steam cylinder and rods connecting the pistons of each pair, a connecting member for all of said rods, a steam-distributing mechanism delivering steam to one of the steam-cylinders, and from that cylinder to both of the other steam-cylinders, and an air-distributing mechanism discharging from two air cylinders into the other air-cylinders.

670,153. STEAM-COMPRESSOR. Charles Garver, Fort Wayne, Ind. Filed Mar. 29, 1900. Serial No. 10,585.

A device for utilizing exhaust-steam, a revoluble wheel having a number of pockets within its rim; radial blades adapted to reciprocate in said pockets; ports communicating through the rim of said wheel between said pockets; valves for closing said ports; a casing, inclosing said wheel, eccentrically arranged with one part of its inner surface against the face of said wheel; and the side plates, secured to said casing and having extending cams arranged respectively to alternately close and open said valves.



670,245. AIR-BRAKE. Winfield S. Palmer, Glenburn, Pa. Filed Dec. 5, 1900. Serial No. 38,750.

670,310. PNEUMATIC HUB FOR WHEELS. Theophilus Coad, London, England. Filed Aug. 11, 1900. Serial No. 26,642.

670,399. APPARATUS FOR PUMPING AIR OR GAS. Joseph B. Hilliard, Glasgow, Scotland. Filed Sept. 22, 1900. Serial No 30,850.

670,412. PNEUMATIC TIRE. Pardon W. Tillinghast, Edgewood, R. I. Filed Aug. 14, 1899. Serial No. 727,130.

670,563. AUTOMATIC EQUALIZING CHECK VALVE AND AIR-BRAKE MECHANISM. William S. Morris, Richmond, Va. Filed Sept. 20, 1900. Serial No. 30,599.

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Book Review.

INVENTOR'S MANUAL—How to Work a Patent to Make it Pay. Published by Norman W. Henley & Co., 132 Nassau street, New York. Six and three-quarter inches by five inches, 120 pages. Price, $1.00.

This is a revised edition of a little book giving the observations of "an experienced and successful inventor" and intended to serve as a guide to inventors in perfecting their inventions, taking out patents and disposing of them to the best advantage.

Brief chapters on the faculty of inventing, inventors and inventions properly introduce the subject, but the chief value of the book lies in the chapters on the sale of patents and State laws regulating transfers, instruction for the formation of a company and blank forms for transfer assignment of interests, licenses, royalties, etc.

The material is pertinent, interesting and the printing and binding good.

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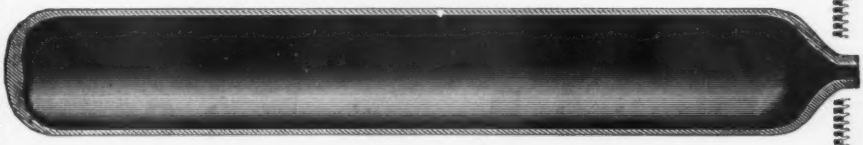

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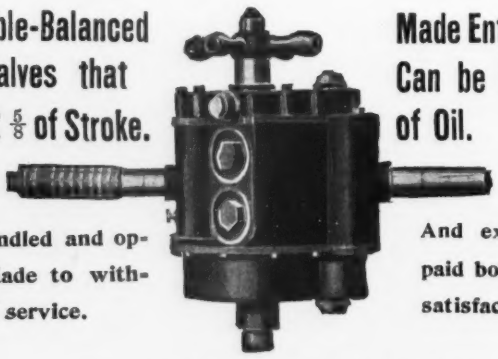

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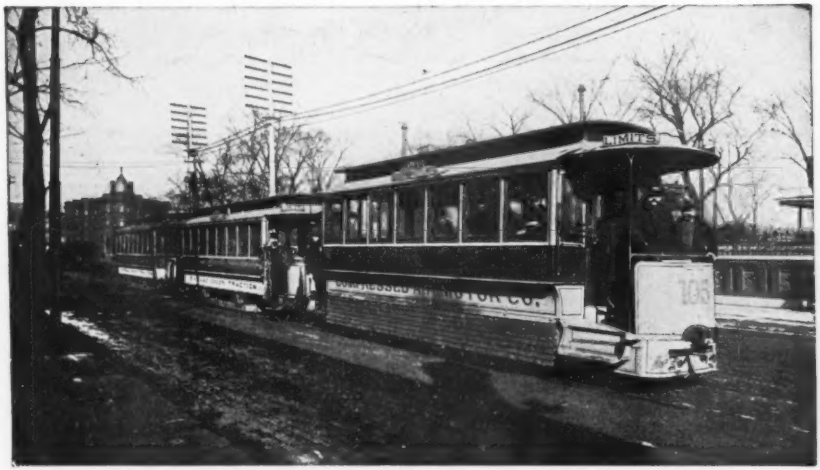

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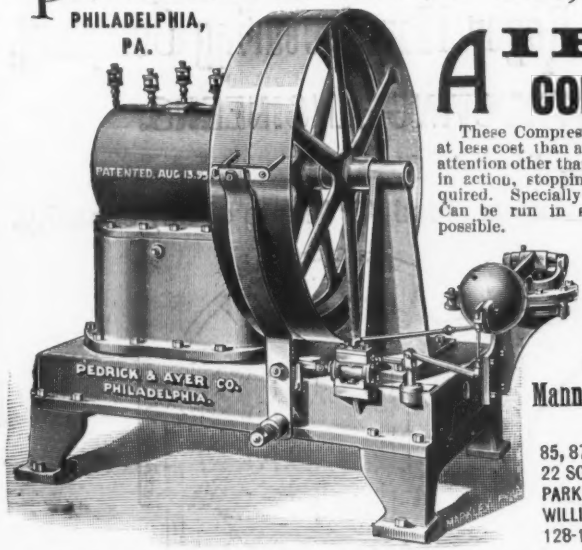

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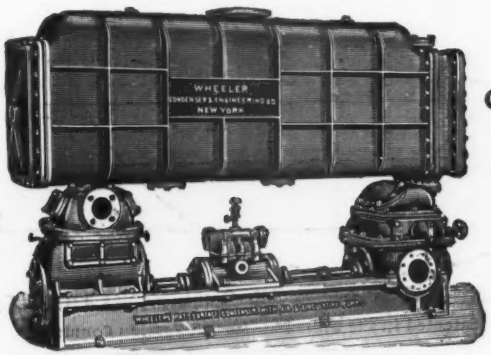

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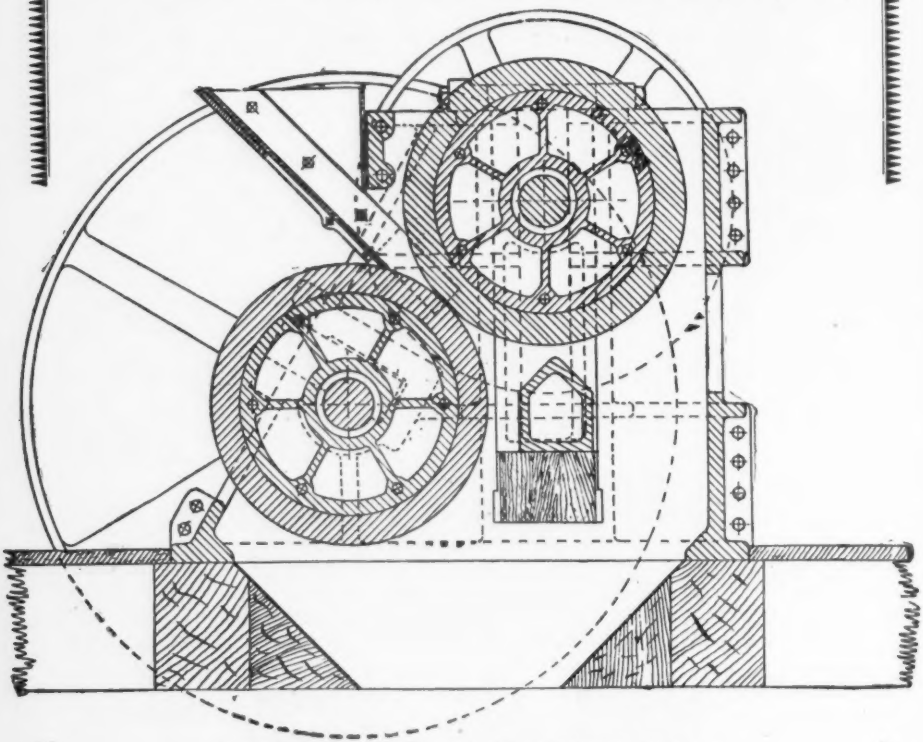

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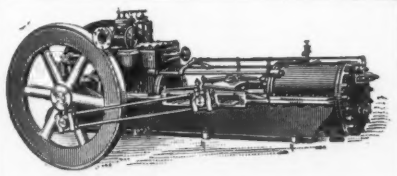

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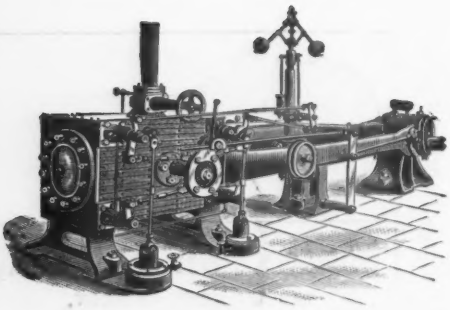

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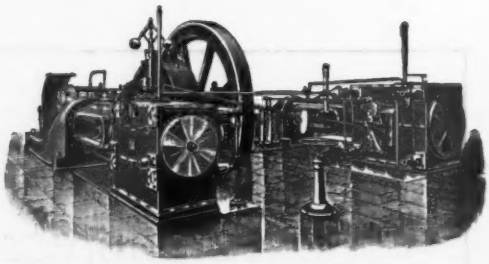

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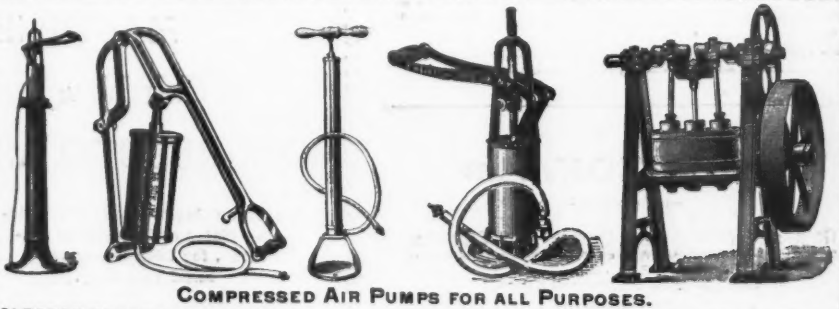

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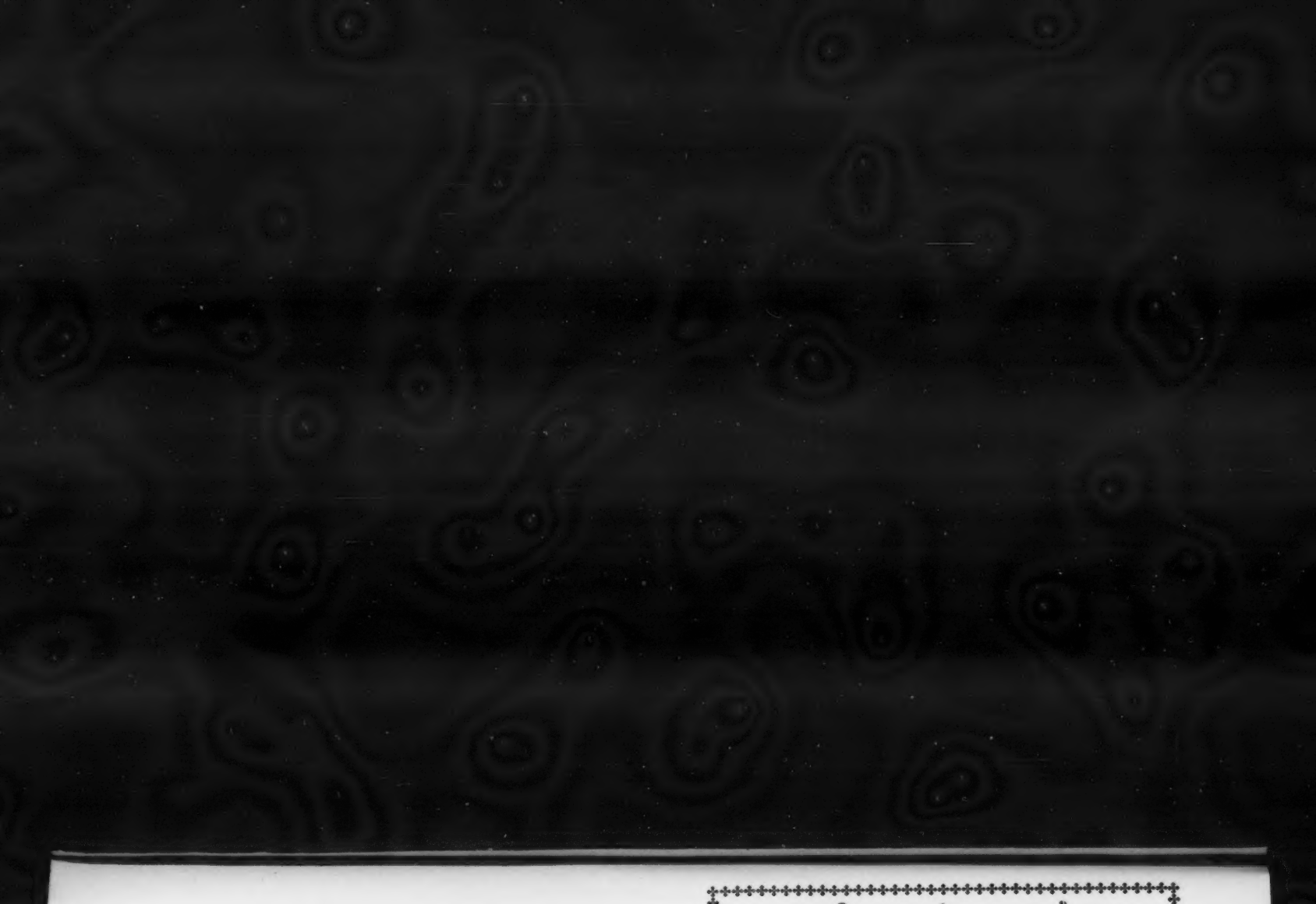

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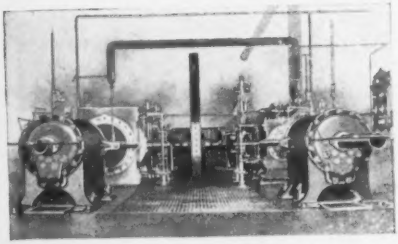

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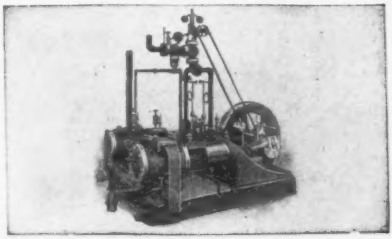

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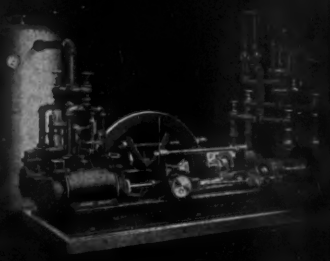

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